TECHNICAL REPORT ECOM-2569

AERIAL RECONNAISSANCE IN THE TROPICS (U)

PROJECT ART

15 MARCH 1965

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(U) FOREWORD

This report contains a liberal sampling of aerial photography and imagery in an attempt to present graphic illustrations of the results obtained during Project ART. It must be pointed out, however, that due to the unavoidable degradations incurred in the photographic reproductions appearing in this report, many of the details contained in the originals were lost. This is particularly true for the color and the halftone reproductions. Some glossy prints are presented in an attempt to preserve the quality of the originals for illustrating purposes; however, the cost of this reproduction method precluded its general use throughout this report.

(U) ABSTRACT

Project ART was a multisensor surveillance exercise conducted by the U.S. Army Electronics Laboratories (USAEL) in the Panama Canal Zone during the early spring of 1964. The primary purpose of the exercise was to collect conventional aerial photography and side-looking airborne radar and infrared imagery over counterinsurgency types of targets and situations in the tropics to be used in the following:

(1) Assessing the value of these sensors for use in counterinsurgency surveillance and reconnaissance work over tropical terrain.

(2) Human factors tests and studies being performed in the development of image interpretation equipments and techniques.

In addition to these sensors, which included three infrared sets, one SLAR, and three aerial cameras, aerial radiometric readings were also taken during Project ART in support of a USAEL meteorological experiment.

The Project ART final report describes the equipments used to obtain the imagery and the radiometric readings, the ground operations, and the data handling in the field and discusses the results of the analysis of the imagery and other data at the Laboratories.

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SECTION 1

(U) INTRODUCTION

The U.S. Army Electronics Laboratories (USAEL) of the U.S. Army Electronics Command conducted a combat surveillance exercise in the Panama Canal Zone during April 1964. This exercise, closely supported by the U.S. Army Personnel Research Office, the U.S. Army Tropic Test Center, and Project MICHIGAN of the Institute of Science and Technology of the University of Michigan, had as its primary aim the acquisition of aerial photography and side-looking airborne radar and infrared imagery over targets that were representative of counterinsurgency operations in an environment generally typical of that existing in Southeast Asia. The exercise, dubbed Project ART (an acronym for Aerial Reconnaissance in the Tropics), actually was one of a series of multisensor exercises conducted during the past three years by USAEL to obtain simultaneously conventional aerial photography, side-looking airborne radar, and infrared imagery of tactically deployed weapons, vehicles, emplacements, and personnel under a variety of tactical conditions. These multisensor exercises support USAEL's extensive research and development effort in image interpretation equipments and techniques.

In addition, the need for information concerning the utility of these airborne sensors in Southeast Asia is recognized, and thus this need coupled with USAEL's general requirement for tropical imagery suggested that a multisensor exercise be conducted in a tropical environment.

The primary uses for the imagery collected during Project ART were then established as follows:

(1) To assess the value of these airborne surveillance sensors individually and conjointly in detecting and identifying counterinsurgency type of targets in a tropical environment generally similar to that found in Southeast Asia, particularly in South Vietnam.

(2) To be used in the USAEL-sponsored human factors tests and studies which support the Laboratories' research and development effort in interpretation equipments and techniques.

(3) To provide background and imagery for development of surveillance information processing equipments and systems.

(4) To be used in the improving of these sensors for intelligence functions.

(5) To assist in determining interaction between sensors when used in a multisensor configuration.

(6) To assist in developing and determining the general capabilities and limitations of these sensors for field operations.

(7) To aid in evaluating equipment concepts prior to the development of new generation equipment.

(8) To aid in the development of research keys and target signatures.

(9) To provide a basis for the development of maintenance and logistics concepts.

This report was prepared in fulfillment of items 1, 6, 8, and 9.

In some respects, this test program represented a logical extension of the Air Force's TROPICAN exercise performed in Puerto Rico in March 1963. While both the Army (during Project ART) and the Air Force (during Project TROPICAN) investigated the uses of these sensors to perform counterinsurgency (COIN) surveillance over the jungles and both investigated infrared firepot responses, the Army, in addition, utilized vehicles, boats, and troops trained in guerrilla warfare in authentic stagings of COIN type of situations. In addition, the Air Force restricted their infrared investigations to the short-wave response InSb cell while the Army investigated the infrared band from the shortest infrared waves out to 13.5 microns. Finally, the Army utilized an improved-resolution AN/APQ-86 SLAR, while during TROPICAN the AN/APQ-55 was used.

Chart 1 presents the Project ART test concept, and Chart 2 is a brief listing of the equipments used and the personnel who participated in the exercise.

1. Establish eight controlled target areas in a variety of tropical environmental backgrounds, each control area to contain three or more specific target types.

2. Target types to include cooking fires and campfires, a minimum of three types of combat vehicles, ambush sites, trenches, small boat activity, troops, encampments, bivouacs, camouflage, caves, etc in areas from open grasslands to multistoried rain forests.

3. To overfly these situations with three or more infrared sensors, three or more aerial cameras, and a high resolution side-looking airborne radar.

4. To precisely document and record all "ground truth" information of each situation for reference and study.

Chart 1. Project ART Test Concept

EQUIPMENT

1. JC-47J Aircraft (USAEL - Multisensor)
   a. AN/APQ-86 SLAR
   b. AN/UAS-5 IR
   c. Paired KA-50A Cameras
   d. Radiometer

2. JC-47J Aircraft (Project MICHIGAN - IR Lab)
   a. Modified AN/AAD-2 IR
   b. Modified AN/AAR-9 IR
   c. P-220 Camera
   d. Tape Recorder

3. U-1A Aircraft
   KA-39 Camera

4. Modified AAFCS-M-33 Radar Tracker

5. Processing Van, Radio Trucks, etc

6. Ground Documentation Support Equipment

DIRECT SUPPORT PERSONNEL

USAEL and Ft Monmouth	26
USAPRO	1
HRB-Singer (through RADC)	1
USATTC	4
Project MICHIGAN	12
Albrook AFB, Panama	3
9th Bn, 10th Inf	40
TOTAL	87

Chart 2. Project ART Equipment and Personnel

SECTION 2

(C) EQUIPMENT CONFIGURATIONS

A. GENERAL

Three aircraft took part in Project ART. These three were the multisensor-equipped USAEL JC-47J, Project MICHIGAN's flying infrared laboratory JC-47J, and a single-sensor-equipped U-1A Otter. Figure 1 is a photograph of the USAEL's JC-47J, and Figure 2 of an Otter. The two JC-47J's were multisensor instrumented and along with the Otter were flown in such a manner as to obtain near simultaneous coverage by all sensors of the ground target arrays. The Otter aircraft was also flown in support of the ground truth operation.

B. AIRBORNE EQUIPMENT

1. USAEL JC-47J

The USAEL JC-47J was instrumented with a modified AN/APQ-86 side-looking airborne radar, an AN/UAS-5* infrared system, two KA-50A aerial cameras, and a Barnes radiometer. All sensors were programmed to be operating on each mission, and thus simultaneous ground coverage was provided by the cameras, the IR, and the radiometer. On alternate passes "over" the target arrays, the SLAR provided radar coverage of the ground targets. Figure 3 shows the coverage pattern provided by these four sensors.

25X4

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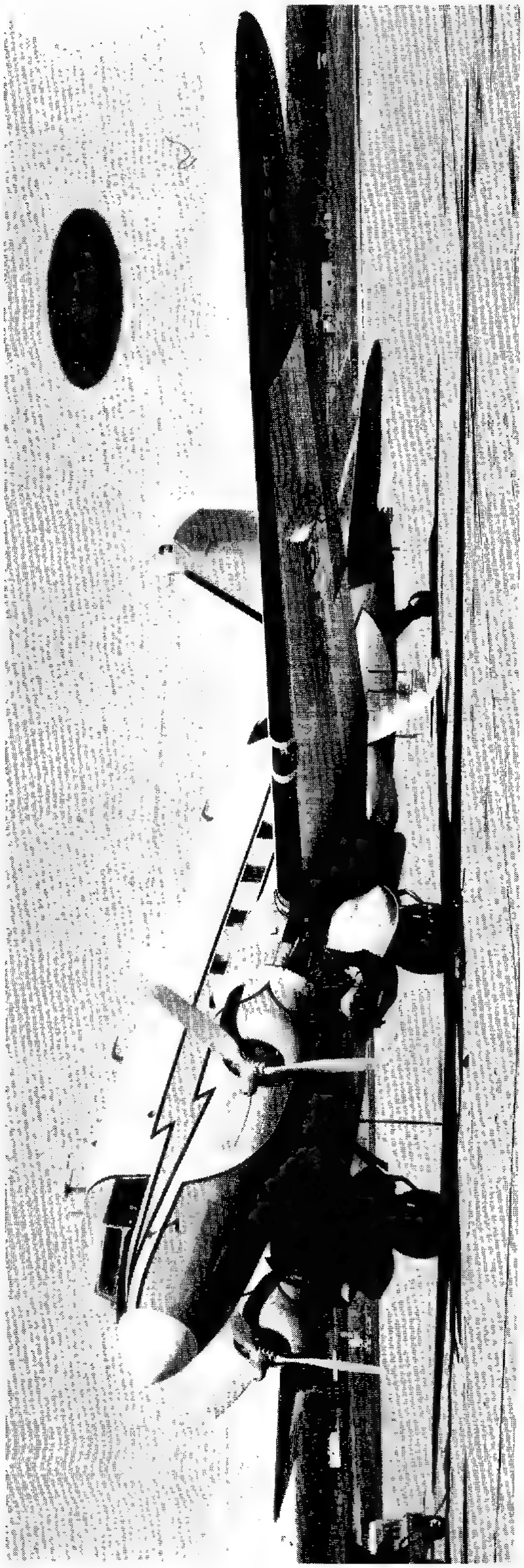

Figure 1. (U) JC-47J

Figure 2. (U) U-1A Otter

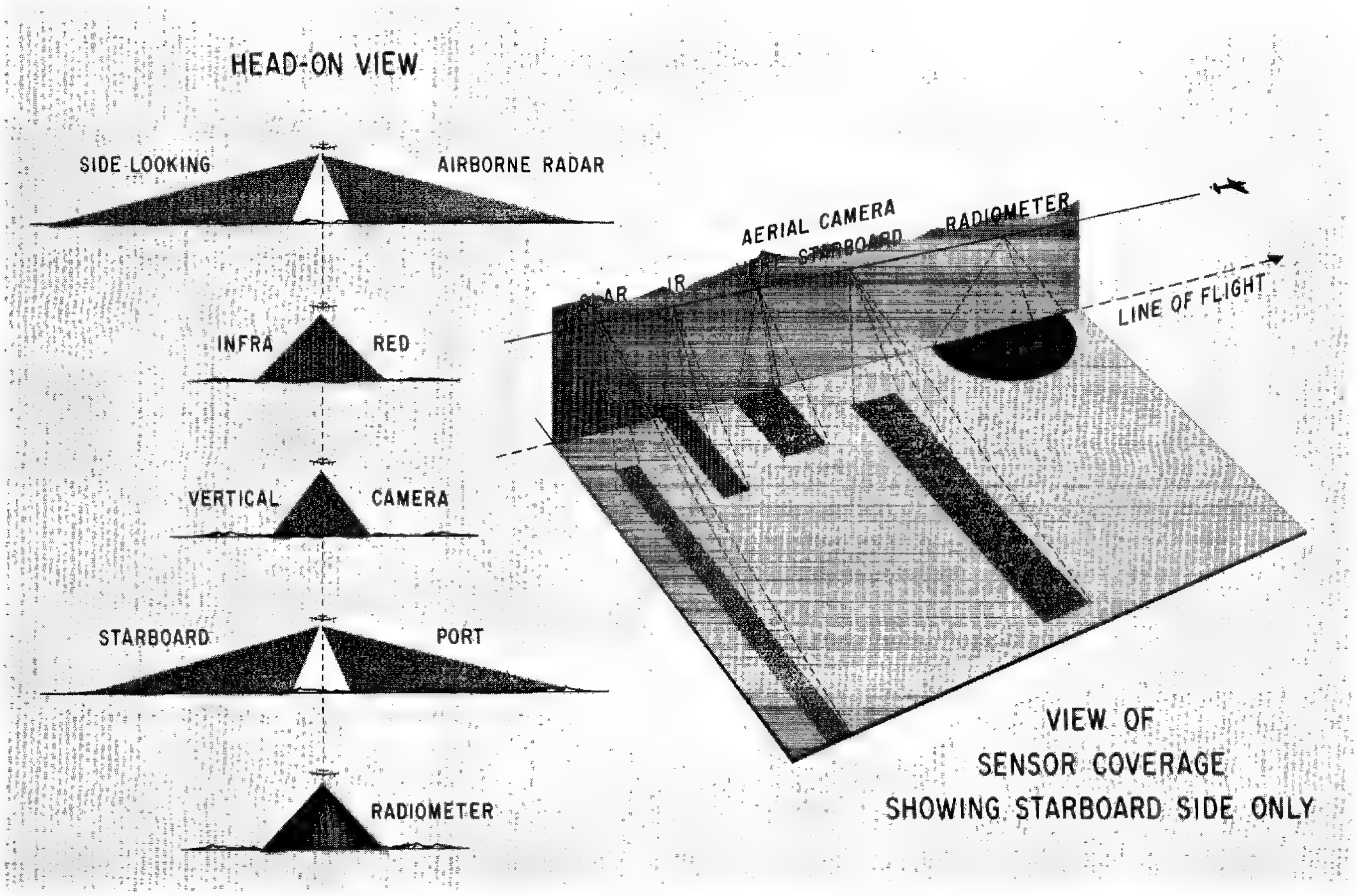

Figure 3. (U) Multisensor Coverage Patterns

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25X4

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the extent that it is affected by the yellow filter. Like its black-and-white counterpart, color IR has a haze penetration potential which when utilized with a blue-eliminating filter seriously limits detail content in shadow areas.

(4) Ektachrome Aerographic Film (E. I. 16), about equally sensitive to all visible colors, was utilized to exploit the different colors of objects, which often is one of the most important clues in photographic interpretation.

d. Barnes Radiometer. The infrared radiometer used in Project ART is a Barnes Portable Radiation Thermometer (PRT), Model 14-310. The system consists of a sensing head, electronic unit, recorder amplifier (laboratory-built), and an Esterline Angus recorder. The radiometer measures temperature by comparing the self-radiation of the target with the known radiation from a black-body reference cavity, controlled at +82°C in this instrument. The entering radiation and cavity radiation are modulated by a two-bladed 90-degree-segment mirror chopper rotating at 100 cps. The voltage output of the instrument is proportional therefore to the differential radiation and can be converted to temperature if the emissivity of the target is known. The readout is a direct reading of temperature in the range of -40 to +60°C. A filter restricts the spectral range to 7.5 to 13 microns in wavelength, thus avoiding absorption by carbon dioxide, water vapor, and other constituents of the atmosphere.

The field of view of the PRT is 20 degrees. When looking normally at a surface target area from an altitude of 100 feet, the instrument measures the average surface temperature of a circular area of approximately 1000 square feet.

2. Project MICHIGAN JC-47J

The Project MICHIGAN JC-47J is instrumented with two infrared scanners and a small-format aerial camera. (The photography taken with this camera was poor and not utilized; hence, no further reference to this camera or the photography is made.) In addition to the scanner equipment, instrumentation is included in the aircraft for monitoring scanner performance and for both film recording and tape

recordings of the outputs of the scanners. While only two scanners may be flown simultaneously in the Project MICHIGAN configuration, three scanners were taken to the field in order to exploit the variety of conditions expected in Project ART.

a. M-1 Scanner. The M-1 scanner was built by Project MICHIGAN and uses an AN/AAR-9 four-sided scanning mirror, parabolic collecting mirror, and gyro-stabilization system. The optical system, with a focal length of 10 inches, is the Newtonian type to permit vertical mounting of liquid-cooled detectors.

While the scanner design permits mounting of either short-wavelength or long-wavelength detectors, the primary mode of operation (and that used in Project ART) is with a liquid nitrogen-cooled indium antimonide (InSb) detector. The wavelength sensitivity of this detector is 1.0 to 5.5 μ; with the filters used in Panama, this band was also broken down to intervals of 2.0 to 2.6 μ and 4.5 to 5.5 μ, providing a capability to successively sample three wavelength regions. With the 1/2 x 1/2 mm InSb detector used in Panama, the instantaneous field of view of the scanner is 2 milliradians.

The scanning mirror of the M-1 scanner is driven by a variable-speed d-c motor whose speed is adjusted to the proper V/H ratio of the aircraft. The over-all scanning angle is approximately 72 degrees.

A unique feature of the M-1 scanner is the mechanism that permits operation in a "framing" mode. A cam system rocks the scanner in a fore and aft direction, such that each point at ground surface is scanned three times, giving frames of imagery in which ground points are presented from three viewpoints - forward oblique, vertical, and rearward oblique. This framing mode of operation was developed to explore detection probability as a function of multiple-looking and oblique viewing. In addition, the necessary condition for infrared stereoscopy is met. While available during Project ART and programmed for use at the end of the field effort, this "framing" mode was not used due to aircraft problems that forced early completion of Project MICHIGAN participation.

b. M-2 Scanner. The M-2 scanner is functionally similar to the M-1 scanner. Evolved from the M-1, this scanner differs in having improved electronics and

in-flight selectable focal length; through a folding mirror system, both 10-inch and 20-inch focal lengths are selectively available. The M-2 was developed particularly for studying high resolution infrared effects and provides a 1/2-milliradian field of view when used with the 20-inch focal length optics and a 1/4 x 1/4 mm detector. The M-2 does not have a "framing" mode of operation. In Project ART, only the 10-inch optics were used, which in combination with the 1/2 x 1/2 mm detector used, provides a 2-milliradian field of view.

c. <u>D-2 Scanner.</u> This scanner, officially designated the AN/AAD-2, is on loan to the University of Michigan from the U. S. Army Cold Regions Research and Engineering Laboratory. The D-2 has been modified to accept the large Dewars associated with long-wavelength detectors and to improve electrical bandwidth. The primary mode of operation is with a liquid-helium-cooled, mercury doped germanium (Ge:Hg) detector sensitive to wavelengths of 8.5 to 13.5μ. The system has 3.25-inch collecting optics with a 6-inch focal length; the instantaneous field of view of the scanner when equipped with a 1/2 x 1/2 mm detector such as that used in Project ART is 3.0 milliradians. The over-all scanning angle is approximately 120 degrees.

Of the three scanners, only the D-2 has an internal recording system. In the scanner, a glow-tube modulated by amplified signals from the detector is used to expose 70-mm format film. While not having internal recording systems, both the M-1 and the M-2 scanners are equipped to feed detector signals to a recording rack in the JC-47J aircraft so that oscilloscopic exposure of 70-mm film in a direct record mode is possible.

The primary configuration, and that used in Project ART missions, has either the M-1 or the M-2 in one instrumentation well of the aircraft and the D-2 scanner in the other well. With this combination, spectral sampling of 1.0 - 5.5μ, 2.0 - 2.6μ, or 4.5 - 5.5μ (selected in-flight), and 8.5 - 13.5μ is simultaneously possible. With this configuration, both inflight direct-record imagery and tape-recorded signals are provided. In the presentation of Project ART infrared results contained in this report, only direct-record imagery, contact printed from the direct-record 70-mm film, is presented.

3. U-1A Otter

The Otter aircraft was instrumented with a KA-39A camera.

a. KA-39A Camera. Manufactured by Chicago Aerial Industries for use in the SD-1 Drone and the L-19A manned aircraft, the KA-39A was designed for low-to-medium altitude day-or-night photographic reconnaissance. It utilizes a 6-inch focal-length lens having a 37-degree half-angle field of view. The maximum aperture setting is f/6.3, and the two shutter speeds in the day mode are 1/150 and 1/300 second. The camera requires 28 VDC for automatic operation and employs a between-the-lens shutter. The camera uses a 75-foot capacity film magazine with a 9-inch by 9-inch format, which has a maximum number of 95 exposures per roll.

The KA-39A used primarily standard-speed panchromatic Eastman Kodak Plus-X Aerecon Film (Type 8401, E.I. 80). On two flights, however, experimental Ultra-Speed Anscochrome Film (FPC 132 ASA 200) was used in this camera.

C. GROUND EQUIPMENT

The primary items of ground equipment were a ground-tracking radar and ground-to-air radio equipment. Various and sundry meteorological equipments were also employed; however, all ground equipments represented support units only.

1. AAFCS M-33 Ground Tracking Radar

A modified AAFCS M-33 ground tracking radar was used to record aircraft position data and to control and maintain flight lines of the Laboratories' JC-47J under beacon track. Flight line control was by voice communication to indicate variations from desired track. This control was especially needed during after-dusk and predawn flights. The plotting board and computer had been modified (on another program) to handle any one of four map scales - 1 : 25,000, 1 : 50,000, 1 : 100,000, and 1 : 250,000. The radar was installed in the fenced-in Hawk Missile area on the Atlantic side of the Canal so as to provide line-of-sight tracking over the target areas.

2. AN/GRC-46 and AN/PRC-10 Radio Equipment

An M-37 truck containing an AN/GRC-46 radio was used for communications between the ground tracker and the aircraft. AN/PRC-10 walkie-talkies provided the ground-to-ground communications between members of the ground truth team. In addition, these radios were also used for ground-to-air-to-ground communications between the aircraft and the ground truth team.

SECTION 3

(C) TERRAIN, CLIMATE, AND TARGET ARRAYS

The Canal Zone was selected for these tests because of its close similarity to that of Southeast Asia. The target sites in the Canal Zone were located at elevations ranging from sea level to 400 feet above sea level, which closely approximates the South Vietnam Delta region. The environs of Panama and Vietnam are strikingly similar in climatology and vegetation. Both are monsoonal tropical climates with two seasons, wet and dry, each lasting approximately five months with two months transitional. Temperature averages are almost identical, since the average temperature of Panama is 79°F, and the average temperature for Vietnam is 81°F. Panama has a higher average precipitation with 120 inches a year, while the average precipitation in Vietnam is 90 inches a year. The vegetation of Panama is mainly dense broadleaf deciduous and evergreen, with thick scrub undergrowth and some open savannah grasslands. The vegetation of Vietnam is much the same, having dense broadleaf deciduous and evergreen forests with dense canopies and several stories of thick undergrowth, and some savannah-type grasslands.

Of particularly close similarity to Southeast Asia is the Fort Sherman Area on the Atlantic side of the Canal. Figures 4 and 5 are maps of the Fort Sherman Area, showing the vegetation and landforms respectively.

Despite the fact that Fort Sherman could not support the flight operations of the two JC-47J's, the decision to use this area of the Zone as the tactical exercise area was deemed wise because of the wide range of topographic samples and vegetation conditions and because of the close similarity to Southeast Asia. This decision received further support from the fact that the jungle warfare school was located at Fort Sherman and used this area for training purposes. Assistance

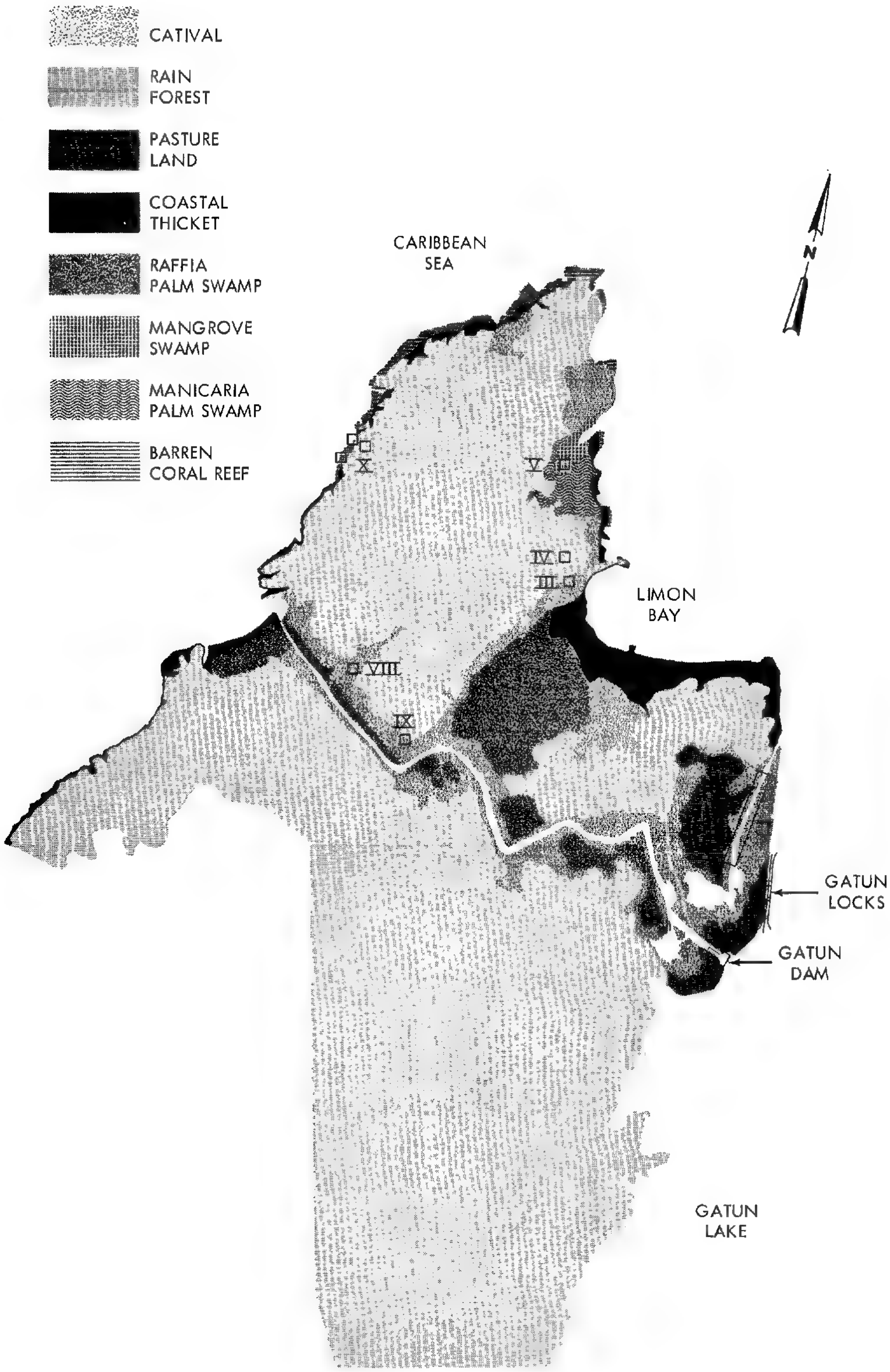

Figure 4. (U) Vegetation - Fort Sherman

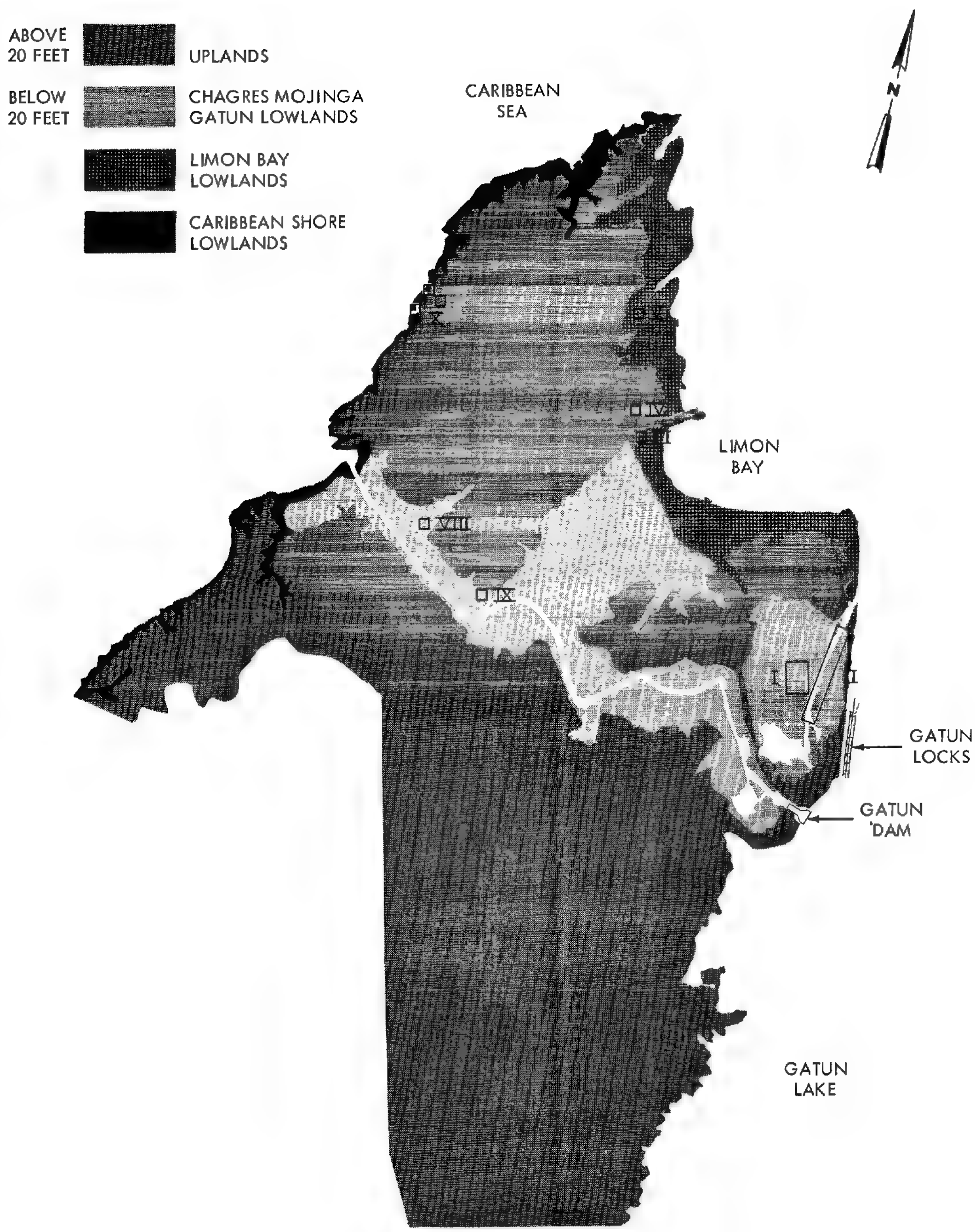

Figure 5. (U) Landforms - Fort Sherman

from the school in setting up and maintaining the ground target arrays was solicited and provided through 1st Lt David Briggs, 3rd Platoon, Company C, 4th Battalion, 10th Infantry, and the 40 men of his platoon.

All of the missions of Project ART were flown in the period 14 - 22 April 1964. In the Canal Zone, April is associated with the transition from the dry, virtually rain-free winter season to the spring rain season. April 1964 proved to be representative of this trend, with the result that the early missions of the project were made during relatively dry-surface, medium-humidity conditions, with subsequent missions under conditions of saturated surface and high humidity. During the exercise period, ambient temperature ranged between 75 and 85°F, with the relative humidity varying between 67 and 97 percent. Cloudiness is also characteristic of the tropical rain season; during Project ART, broken to continuous cloud cover with bases at about 1500 feet was the no-exception rule.

Figure 6 is a map of the Fort Sherman area showing the locations of the 10 ground sites. The locations of these sites were selected in order to present the greatest possible variety of terrain and jungle growth, the vegetation varying from the short-grass savannah at Site I through tropical rain forests with a variety of canopy heights and densities to the heavy single-story jungle growth of Site III. Table 1 gives a brief description of the canopy cover at each of the eight sites implemented. From the map of Figure 6 one can observe how close together substantially different biotic environments were found. Controlled situations were staged at each of these sites to represent a variety of possible guerrilla operations including mounted patrol, road ambush, bivouac (to include vehicle park), and canal crossing. In each case the positions of personnel, guns, vehicles, trenches, and camouflaged and concealed items were photographed in black and white and sometimes in color, and carefully plotted on sketch maps. Later these positions were plotted on the large-scale aerial KA-39A photographs of the sites taken from the Otter aircraft. During the period that aircraft were obtaining imagery, detailed temperature, relative humidity, and wind velocity data were obtained for appropriate points within each site. Numerous ground photographs were taken at each site to support the subsequent interpretation of aerial imagery.

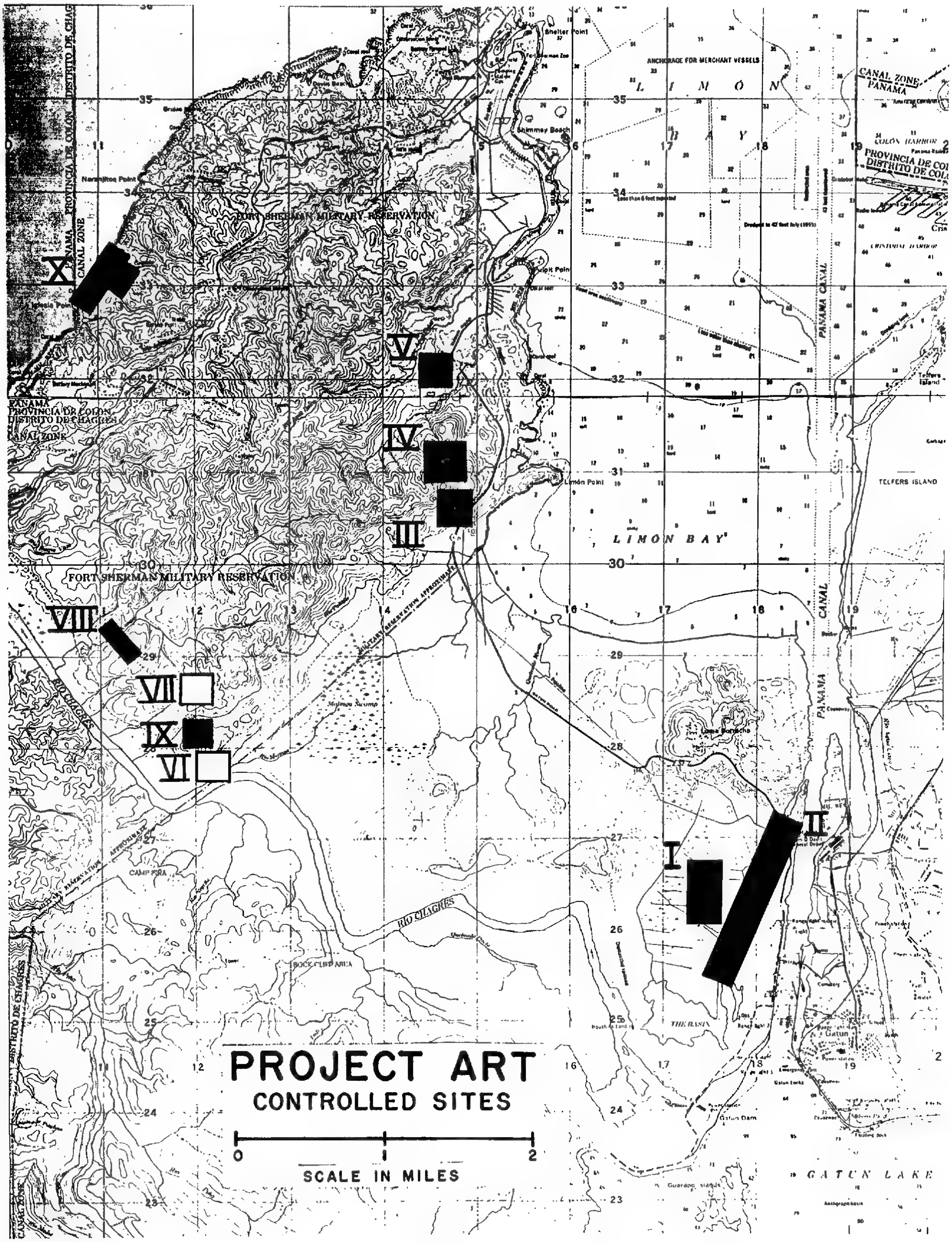

Figure 6. (U) Project ART Site Locations

Table 1. Description of Canopy at Each Site

Site	Canopy	
	Density	Remarks
I	None	
IV	Light	25 years old, second growth, 30-40 feet
II	Medium	
V	Medium	50 years old, 80 feet
X	Medium	
VIII	Medium-Heavy	60 years old, 80 feet
IX	Medium-Heavy	60 years old, 80 feet
III	Heavy	

SECTION 4

(C) DESCRIPTION OF SITES

A. SITE I

Figure 7 is a detailed sketch of Site I. Initially, as represented by this site, all vehicles, entrenchments, and firepots as noted here were in the open as were also six personnel. The sizes, separations, and alignments of the firepots and entrenchments and the fact that they were deployed in clear line-of-sight of the overflying aircraft was intended: first, to represent the flat tall-grass savannah situation found in Southeast Asia; second, to provide opportunity for obtaining basic signatures of the target elements to be used in subsequent staging of tactical targets; and third, to allow for resolution studies of the airborne sensors. The two small firepots were six inches in diameter, and the large one was 12 inches in diameter. These charcoal firepots were used here and in subsequent target stagings to represent hibachi-type pots used by Southeast Asians for cooking and warming. The entrenchments from left to right in Figure 7 were the following length, width, and depth respectively:

Length (ft)	Width (ft)	Depth (ft)
6	2.5	1
6	2.5	1
10	2.5	1
10	2.5	1
10	2.5	1

In addition, the entrenchments were under various degrees of camouflage. (One foxhole was completely camouflaged.) During overflights of this site, the engines of the 2-1/2 ton and the 3/4-ton vehicles on the road and the 3/4-ton and the 1/4-ton vehicles parked off-road in the grass (the hashed rectangles of Figure 7) were

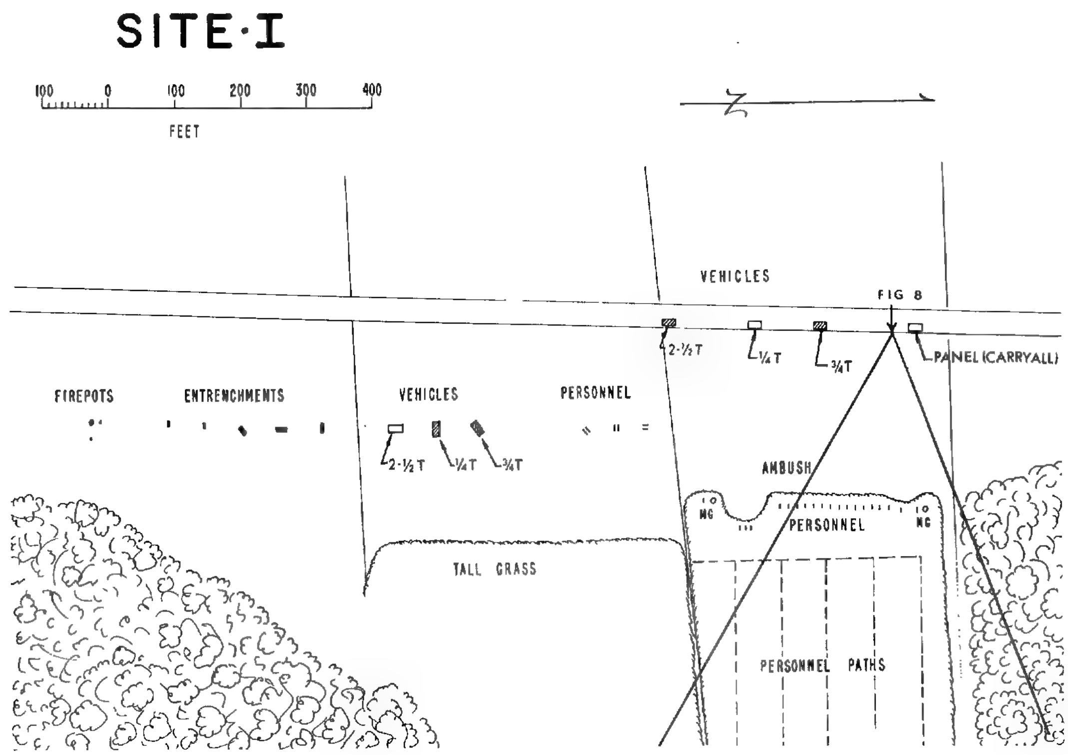

Figure 7. (U) Detailed Sketch of Site I

Figure 8. (U) Ground View of Ambush at Site I Taken from the Road

at operating temperature. All other vehicles had engine temperatures near ambient.

The personnel lying in the short savannah grassland were lying in groups of two in three different directions, each group separated by about 30 feet, and each person within a group by about 10 feet. In addition to these people in the clearing, there were 18 men lying in ambush in the tall savannah grass and four other men manning two concealed machine guns. Figure 7 shows the configuration of the ambush situation, and Figure 8 shows how this ambush site appeared from the road. The dashed lines of Figure 7 marked "personnel paths" were paths taken by the troops through the six-foot grass to get to the woods (not shown on the sketch). These paths were accurately controlled and recorded to determine whether the paths left by infiltrating guerrillas through such growth could be detected from aerial imagery. The three long lines perpendicular to and on each side of the road are drainage ditches.

B. SITE II

As can be seen from the map of Figure 6, this site was located along a portion of the French Canal with lush overhanging vegetation and a road paralleling the Canal. At this site there were established three tactical guerrilla situations as shown by the sketch (Figure 9). A seven-vehicle convoy with four motors off and three on, in the configuration shown, was staged along the road. An ambush position consisting of 13 riflemen and two machine guns was set up along the Canal, and three small boats typical of the type currently being used by the Viet Cong in Vietnam were placed in the Canal. Two of the boats, one with an outboard motor and manned by two men and the other a cayuca and manned by three men (see Figure 10), plied the Canal in a manner that might be ascribed to infiltrating guerrillas. The third boat, a cayuca with three men aboard (see Figure 11), remained tied to a large tree and was partially concealed from aerial view by the tree. In addition to these three situations, a six-inch firepot was placed on the road at the south end of the vehicle convoy.

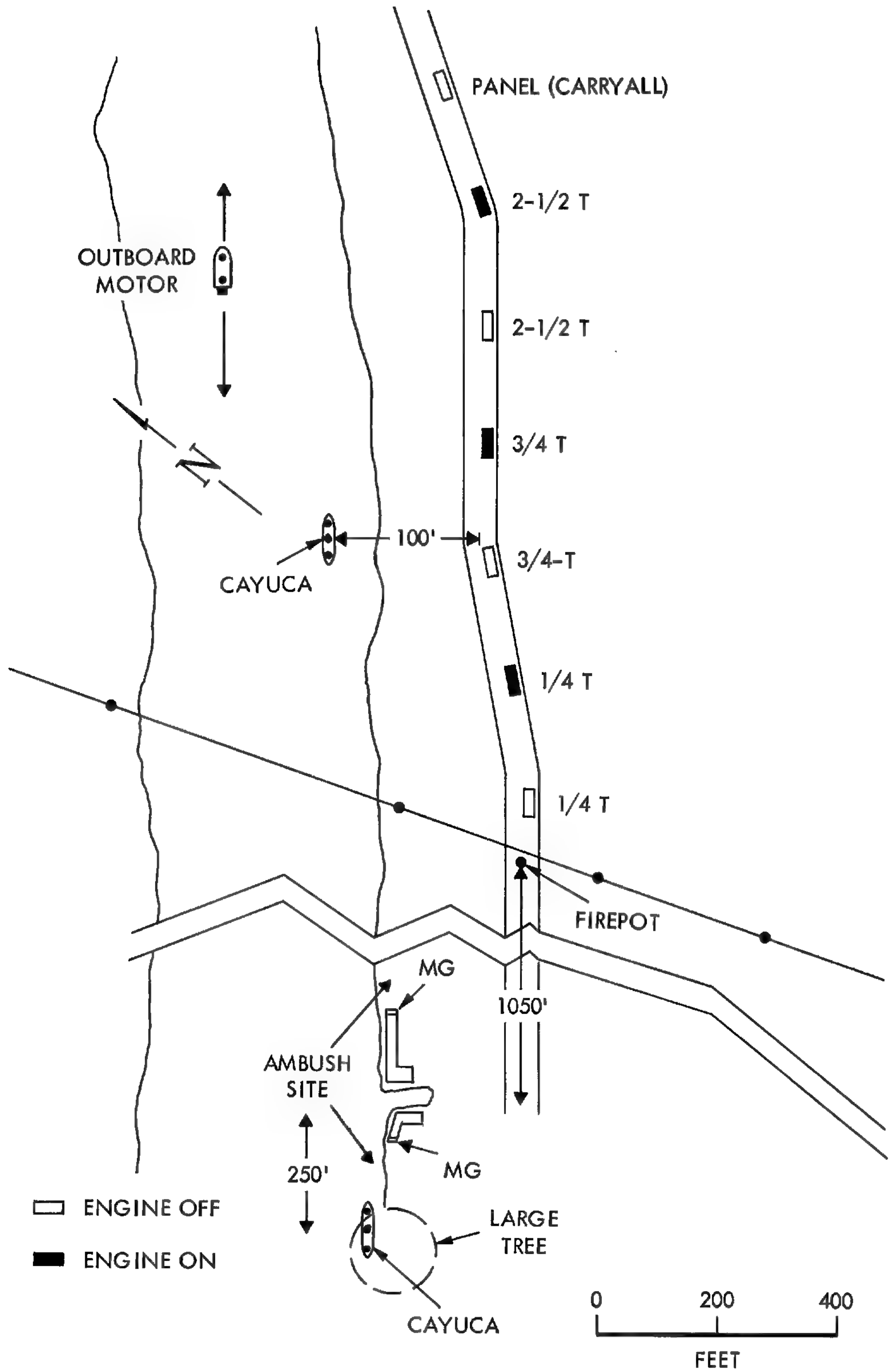

Figure 9. (U) Detailed Sketch of Site II

Figure 10. (U) Cayuca in Open Water at Site II

Figure 11. (U) Partially Concealed Cayuca at Site II

C. SITES III AND IV

These sites, the locations of which are shown in Figure 6, were staged simultaneously and in close proximity and will therefore be discussed together. Site III, which is shown as part of Figure 12, was arranged to simulate a guerrilla bivouac area and consisted of 26 men and a group of 6 charcoal firepots of three different diameters (3-inch, 6-inch, and 12-inch) arranged as shown in the sketch. A pattern was selected with an eye toward making detection easier. This particular spacing of the firepots within the pattern was set to give varying degrees of canopy cover. This group was placed in an area of hilly, mature tropical rain forest, an area in which the forest canopy, while single-storied, was very dense. Men sat around three of the firepots to further simulate guerrilla campfires and bivouac.

Site IV, located slightly north of Site III in multistory, second-growth vegetation and shown as the other part of Figure 12, was intended to simulate a seven-vehicle road patrol. The trail on which the road patrol was located was a narrow, dirt trail intermittently obscured by overhanging vegetation, with the result that the emplaced vehicles were generally masked from vertical observation. Figure 13, a ground photograph showing the lead vehicle of the convoy, is presented here to demonstrate the degree of canopy coverage provided for the first two vehicles.

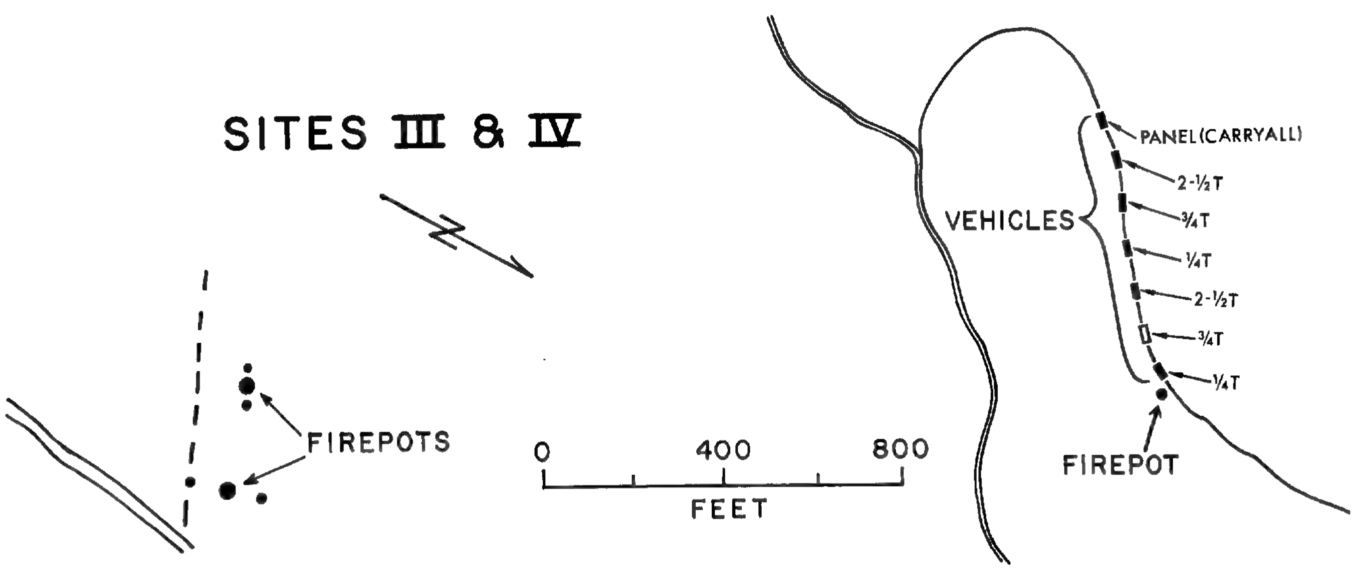

Figure 12. (U) Detailed Sketch of Sites III and IV

Figure 13. (U) Ground View of Leading Vehicles of Convoy at Site IV

The coverage became progressively more dense along the convoy. A six-inch firepot located in a clearing 28 feet due north of the rain gauge and at the northern end of the convoy was sited as a reference point. All vehicles at Site IV except the northernmost 3/4-ton truck were "engines-on" during all infrared overflights.

D. SITE V

This site, shown in Figure 14, was established in the tropical rain forest near a meteorological tower which protudes about 80 feet above the jungle canopy. The trees in this area are about 50 years old and about 80 feet high. The targets themselves at this site consisted of a special "non-tactical" situation. Cooking and warming fires, generally of charcoal, have been identified as indicators of Southeast Asia guerrilla activities and as potential targets for infrared reconnaissance. In an attempt to get an adequate sample of firepot detection, this site was thereby staged. As shown in Figure 14, Site V consisted of an array of 14 charcoal firepots. The firepots ranged in size from a 6-inch diameter pot atop the 160-foot tower shown near the center of the array to a 12-inch diameter fire, with the latter size being the more numerous. These pots, except for the one on the tower, were located at ground level in a hilly area covered with multistoried vegetation. While the density of vegetation cover differed from pot to pot, none of the pots was completely in the open except the tower pot. This array of firepots was lighted during each of the planned airborne infrared missions over the tactical targets, and the flight program was arranged so that several passes were made over Site V on each of the missions. Thus, imagery of Site V was obtained under the several time-of-day, altitude, wavelength, and scanner-type conditions of the field exercise. The tower itself was instrumented with hydrothermographic equipment, and various meteorological data were collected. Figure 15 is an aerial, low-altitude, low-oblique view of Site V near the tower showing the apparently impenetrable jungle canopy.

E. SITES VI AND VII

These two sites were planned for the positions indicated on the map of Figure 6. However, because of time pressure, they were never implemented.

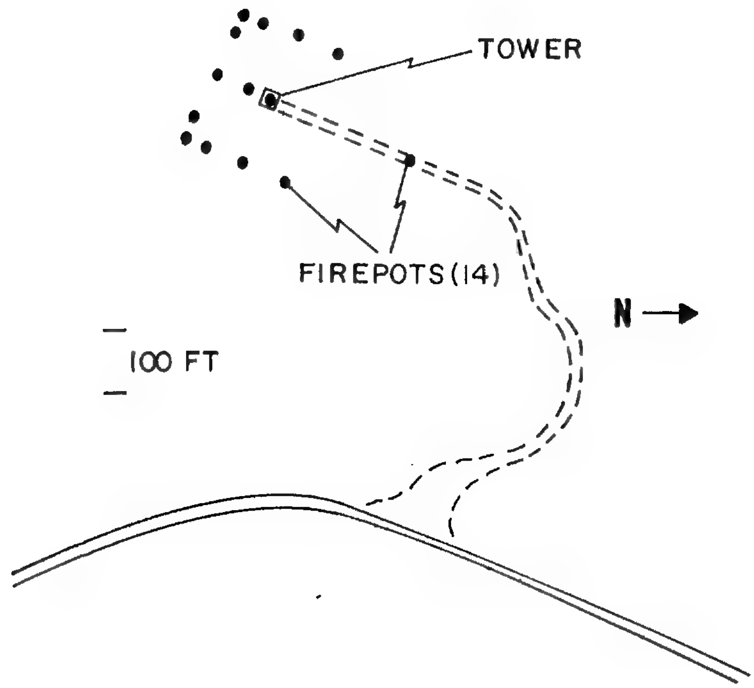

Figure 14. (U) Detailed Sketch of Site V

Figure 15. (U) Aerial Oblique of Canopy Cover and Meteorological Tower at Site V

F. SITE VIII

The bridge across the Rio Congo River, as seen from the ground in Figure 16 and from the air by way of a high oblique in Figure 17, was the location of Site VIII. This site was intended to simulate the preparation of a road ambush situation with weapon and guerrilla-carrying vehicles still in the area. Vegetation in the area was of the multistory, second-growth type typical of tropical areas. This vegetation canopied over the trail in such a way that the trail was only intermittently visible from overhead. Figure 18 is a sketch of this site, showing the orientation and position of each of the seven vehicles. A six-inch firepot was placed at the northwestern edge of the site for reference purposes. The vehicle types, parked on the trail and with engines off, were the same as those used for Sites I, II, and IV, spaced 75 feet apart.

G. SITE IX

Figure 19 shows Site IX along a jungle trail where a road ambush was established. Immediately to the right of this point can be seen the screen of vegetation shown in Figure 20, which was photographed approximately five feet from the forward edge of the vegetation screen. Figure 21 shows a view of this ambush site from behind. A firepot was also placed in a clearing at this site for reference purposes.

H. SITE X

At Site X along the sea coast, the geographical location of which is shown on the map of Figure 6 and an aerial view of which is shown in Figure 22, a series of natural sea caves was utilized. Firepots were placed in three of the caves along the shore. Figure 23, a ground photograph of one of these caves, shows one of the firepots. Beyond the caves in a small clearing was staged a bivouac of a mounted unit. Six vehicles were emplaced on the perimeter of a small clearing at the end of a trail in multistory second-growth vegetation. (A seventh vehicle, a 3/4-ton truck, was parked behind the panel truck on 20 April 1964 between 1900 and 2100 hours.) A firepot was placed in the center of the clearing as an infrared reference source. Figure 24 shows the layout of Site X. During the infrared missions, only two of the vehicles were engines-on - the 2-1/2 ton truck on the northwest perimeter and the 1/4-ton truck more distant from the firepot.

Figure 16. (U) Bridge across the Rio Congo River at Site VIII

Figure 17. (U) Aerial Oblique of Canopy Cover at Site VIII

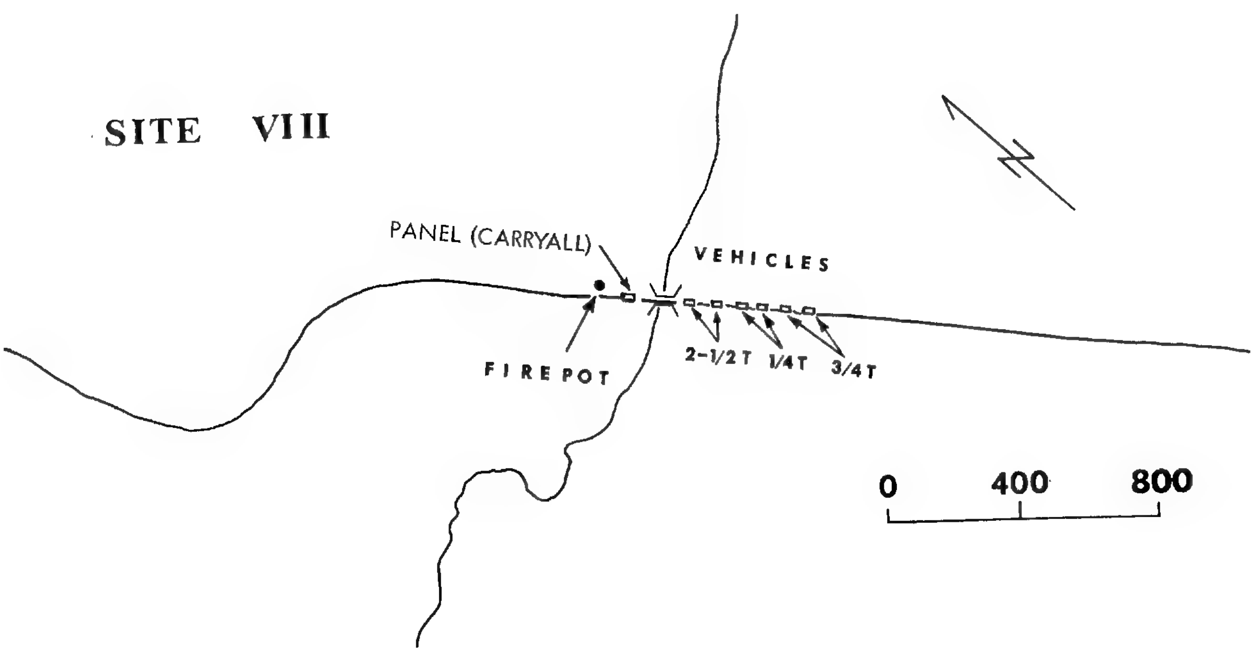

Figure 18. (U) Detailed Sketch of Site VIII

Figure 19. (U) View of Jungle Trail Used as the Location for Site IX

Figure 20. (U) Ground View of Ambush at Site IX Taken from the Road

Figure 21. (U) Rear View of Ambush at Site IX

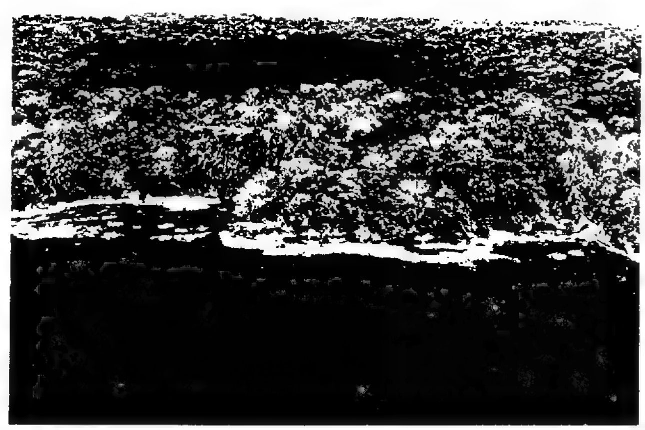

Figure 22. (U) Aerial Oblique Showing Sea Caves and Canopy Cover at Site X

Figure 23. (U) Typical 12-Inch Firepot Placed in Sea Cave at Site X

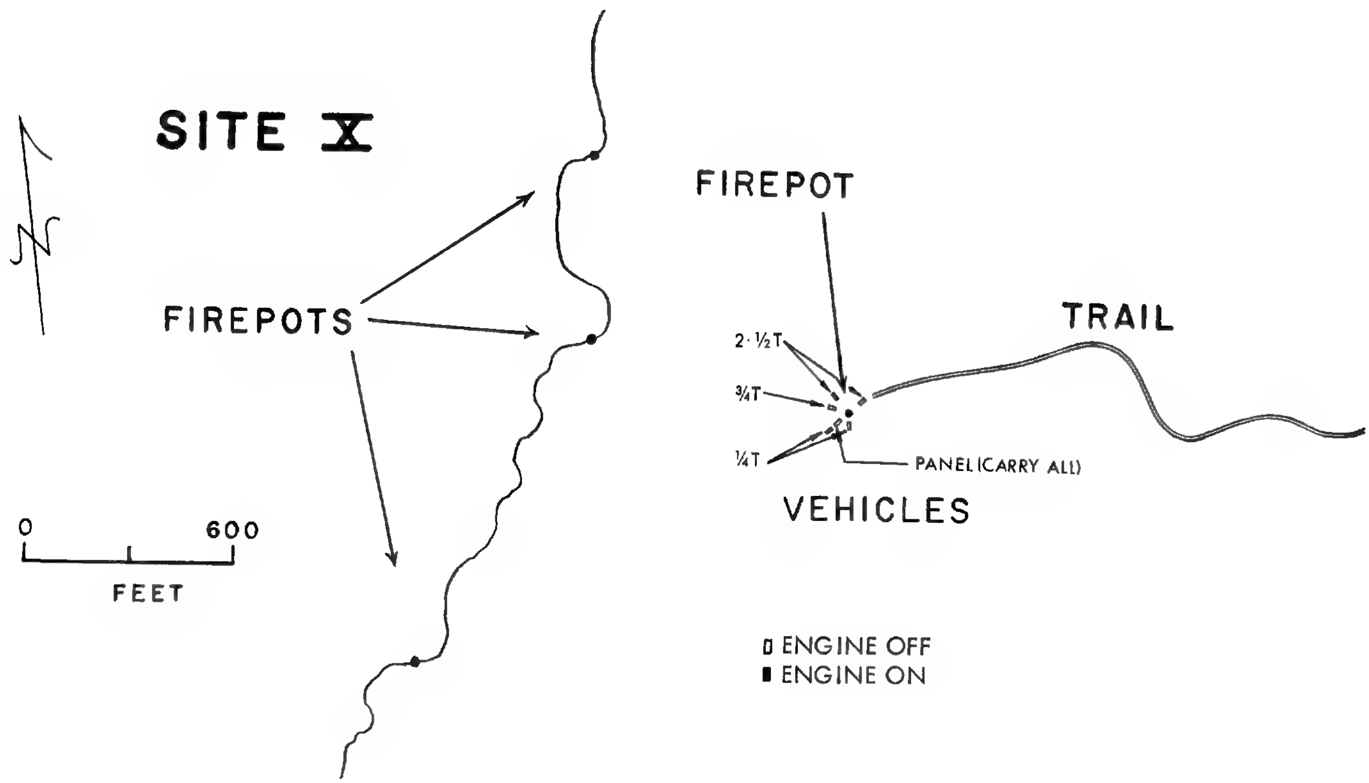

Figure 24. (U) Detailed Sketch of Site X (description on p. 29)

SECTION 5

(U) FLIGHT OPERATIONS AND DATA HANDLING IN THE FIELD

Forty-seven sorties were flown by the three test aircraft, 38 of which (17 by the Laboratories' JC-47J, 12 by Project MICHIGAN's JC-47J, and 9 by the Otter) were imagery-acquisition missions. The other nine sorties served as equipment check-out flights and, in general, were flown prior to the controlling of the ground situations. Chart 3 is a detailed breakdown of the missions as they were flown, along with a brief indication as to the degree of success of each sortie. Table 2 defines the letters used in this chart to specify the infrared regions investigated.

Table 2. Infrared Regions Investigated during Project ART

Letter	Definition
W	1.0 - 5.5μ
S	2.0 - 2.6μ
M	4.5 - 5.5μ
L	8.5 - 13.5μ (this is the range of the newer systems)
A	3.0 - 5.5μ
B	3.0 - 4.5μ

Chart 4 indicates the times that each site was staged.

Data obtained during the tests fell basically into one of three categories:

(1) The sensor imagery (to include aerial conventional photography)

(2) The sensor operator's logs and the M-33 ground track plots

(3) The ground truth

The sensor imagery was processed immediately upon the termination of the flight. (Mission numbers 208 and 209 were exceptions since the test film used was specially

Date (Apr)	Time	Mission	Site	SENSORS									Remarks
				SLAR	IR Scanner		Cameras						
							Station No. 1			Station No. 2			
				Quality	IR Region	Quality	Film	Filter	Quality	Film	Filter	Quality	
8	1409 - 1412	PFM 1			M, L								
10	0850 - 1000	PFU 1		Poor	M		Black & White		See remarks	Black & White		See remarks	No photography - shutter malfunction on both cameras.
10	1420 - 1452	PFM 2			M, L								
10	1902 2020	PFM 3			W, L								
10		PFO 1											
11	0428 - 0514	PFM 4			W, L								
11	0915 - 1044	PFU 2		Fair	M		Plus-X	Anti-Vig G12	Good	Plus-X	Anti Vig G12	Good	
11	0945 - 1100	PFO 2					Plus-X Pan						
12	1050 - 1215	PFU 3			A		Ekta-chrome	Anti-Vig	Good	Color IR	Anti-Vig WR G12 plus A CC 10M	Good	
13	1000 - 1100	201	I				Plus-X Pan	Anti-Vig Clear	Good				
13	1035 - 1238	101			A		Black & White		See remarks	Black & White IR	Anti-Vig WR 89B	Fair	No photography at station shutter malfunction.
14	0410 - 0500	301	I		W, L	Good except runs 1 & 2							
14	0526 - 0633	102	I, X	Fair	W	Fair to poor							Predawn - no photography.
14	0830 - 0930	103	I, X		A	Fair	Black & White IR	Anti-Vig WR 89B	See remarks	Color IR	Anti-Vig WR G12 plus A CC 10M	See remarks	No photography - shutter malfunction on both cameras.
14	1115 - 1205	302	I		W, S, M, L	Good except runs 1 & 4							
14	1100 - 1145	202	I, III				Plus-X Pan	Anti-Vig Clear	Fair				
15	0410 - 0505	303	III, IV, V		W, L	Good							
15	0527 0612	104	III, IV, V		W	Fair to poor							No photography predawn flight.
15	0801 - 0841	304	III, IV, V		W, S, M, L	Good							
15	0907 - 1054	105	III, IV, V, X		A	Fair	Black & White IR	Anti-Vig WR 89B	Good	Color IR	WR G12 plus A CC 10M Anti-Vig		
15	1000 - 1130	203	III, IV, V				Black & White IR	Anti-Vig Clear	Good				
15	1430 - 1600	204	VI, VII, VIII, IX, X				Plus-X Aerecon	Anti-Vig Clear	Good				
15	1902 - 2000	106	III, IV, V, X	Fair	W	Fair to poor							Night - no photography.
15	2013 - 2105	305	III, IV, V		W, L	Good							
16	1915 1937	107	VIII, IX	Poor									Night - no photography
16	2013 - 2108	306	III, IV, V, VIII, IX		W, L	Good							
17	0402 - 0434	307	III, IV, V, VIII, IX		W	Good							
17	0515 - 0627	108	VIII, IX		W	Fair							Predawn - no photography.
17	0809 - 0907	308	III, IV, V, VIII, IX		W, S, M	Good							
17	0930 - 1052	109	VIII, IX	Good to poor	A	Fair	Ekta-chrome	WR 1A	Good	Black & White Plus-X	Anti-Vig G12	Good	
17	1130 - 1215	205	VIII				Plus-X	Anti-Vig Clear	Good				
18	1440 - 1455	309			M	Poor							
20	0353 - 0447	310	III, IV, V, X		W	Good							
20	0540 0628	110	X	Poor	W	Fair to poor							Predawn no photography.
20	0802 - 0833	311	III, IV, V, X		W, M	Good							
20	0934 - 1026	111	X	Poor	W	Fair to poor	Ekta-chrome	WR 1A	Good	Color IR	Anti-Vig G12 CC 10M	Good	
20	1100 - 1145	206	X				Plus X	Anti Vig clear	Good				
20	1859 - 2012	112	X		W	Fair to poor							Night flight no photography.
20	2008 - 2032	312	III, IV, V, X		W	1-3 good 4-8 poor							
21	1904 - 2007	113	II	Poor	W	Fair							Night flight no photography.
22	0442 - 0515	114	II		W	Fair							Predawn - no photography
22	0934 - 1030	115	II	Good to poor	B	Fair to poor	Sp Tri-X Gray Base	Anti Vig WR G12	Good	Black & White Plus-X	Anti-Vig WR G12	Good	
22	0930 - 1030	207	II				Plus-X	Anti-Vig Clear	Good				
23	1037 - 1156	116	I	Fair	W	Fair	Ekta-chrome	WR 1A	Good	Color IR	Anti-Vig WR G12 CC 10M	Good	
23	1110 - 1225	208	I, V, VIII				Ansco-chrome 200-ASA	Anti-Vig Clear	Fair				
24	0750	117	I				Black & White IR	WR 89B	Good	Black & White Plus-X	Anti-Vig WR G12	Good	IR scanner and SLAR not operated.
24		209					Ansco-chrome	Anti-Vig Clear	Poor				

Chart 3. (U) Project ART Missions

Site	Date	Time
I	14 April 23 April 24 April	0345 - all day 1100 - 1200 0800 - 0900
II	21 April 22 April	1900 - 2030 0430 - 0530 0930 - 1030
III	14 April 15 April	0400 - 0600 0800 - 1200 0400 - 0600 0800 - 1100 1900 - 2100
IV	15 April	0400 - 0600 0800 - 1100
V	15 April	1900 - 2100
VIII	16 April	1900 - 2100
IX	17 April	0400 - 0600 0800 - 1100
X	15 April 16 April 17 April 20 April	0417 - 0505 0803 - 0841 1145 - 1157 2018 - 2057 2013 - 2040 0402 - 0418 0809 - 0832 0353 - 0447 2008 - 2032

Chart 4. (U) Times of Site Stagings

provided by the General Analine Company and had to be returned to the laboratory for processing.) In general, the order of film processing was SLAR, IR, and conventional photography. Immediately following film processing, the imagery was titled, logged in, and briefly annotated. The primary effort in terms of image interpretation on site during the acquisition effort was devoted to ensuring that the data were properly logged, that briefing and debriefing of the sensor operators prior to and immediately following a flight were properly and expeditiously conducted, and that the imagery was plotted so as to ensure that the desired coverage was obtained during that particular flight. Assistance in G2 air flight planning was also provided by the image interpretation team.

To expedite the handling of the imagery obtained during the flights, the following method of titling or labeling of the imagery was employed. Each roll of imagery was given a three digit number followed by either A, B, C, D, or E. The first of the three digits was either 1, 2, or 3, which identified the aircraft that obtained the imagery in accordance with the following numbers:

(1) USAEL JC-47J
(2) U-1A (Otter)
(3) University of Michigan JC-47J

The second and third digits identified the aircraft's flight or mission number, and the letter indicated the type of sensor used. The following letters applied:

A. Starboard Oblique Photography
B. Vertical Photography
C. Port Oblique Photography
D. Infrared
E. SLAR

When more than one roll of the same type of imagery was obtained on any given flight, the rolls were sequentially numbered, starting from one, and this number was appended to the imagery label.

Logs were maintained by each sensor operator. One man aboard each aircraft was responsible for verifying all information contained thereon. An attempt was

made to debrief the sensor operator after each mission. This was not possible, however, in all cases. This debriefing consisted essentially of a quick study of the sensor data log sheets, of the imagery obtained during the mission, and a brief discussion as to its content and general quality. A determination was also made as to whether there were any deviations from preplanned objectives due to equipment malfunctions.

Maps of the Fort Sherman area were cardboard backed and covered with acetate. Each project key man was supplied with such a map, which was annotated in grease pencil with the flight lines for that particular mission and points at which the sensors were to be turned on and off. Initially, 1 : 50, 000 scale AMS maps were used; however, these very rapidly proved useless because of the large errors they contained. In the vicinity of the Gatun Locks, an error close to 1000 meters was detected on these maps. Use was then made of the larger scale, though considerably more unwieldy, 1 : 25, 000 scale maps.

SECTION 6

(C) DISCUSSION OF MULTISENSOR RESULTS

A. GENERAL

The imagery collected during this exercise was studied and analyzed in accordance with the primary aim of this collection effort, i.e., to assess the value of these airborne surveillance sensors individually and conjointly in detecting and identifying counterinsurgency-type targets in a tropical environment. To this end, the three separate groups who were operating airborne sensors performed their own data reduction, analysis, and interpretation of results. Systems Division* of USAEL, in addition to being responsible for the test planning, data collection, and all attendant logistics and support problems, was also responsible for the analysis of the imagery collected by the KA-50A and the KA-39A cameras, the AN/APQ-86 SLAR, and the AN/UAS-5 IR system, as well as for the multisensor aspects involved in a comparative sensor cover analysis. To accomplish the comparative sensor cover analysis, the simultaneous utilization of the outputs of more than one type of sensor for both detection and identification was studied for each of the sites and for each group of target configuration or situation within a site. A discussion of the results of these sensors and of the multisensor aspects of the tests is presented in the following paragraphs. The Meteorological Division of USAEL operated the airborne radiometer and performed the necessary data analysis. A discussion of these results is also presented. Project MICHIGAN personnel analyzed their own imagery, and their results are also discussed.

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*As of 1 January 1965, the USAEL group responsible for Project ART became known as the Image Interpretation and Transmission Technical Area.

Throughout this exercise the AN/UAS-5 Infrared System, because of its age and continued and long-term use, generally operated poorly. The fact that this system was in poor repair or essentially worn-out was fully known prior to the exercise; however, it was felt that an infrared scanner aboard a second aircraft would be prudent in the event of aircraft problems with the University of Michigan's JC-47J. Thus, the AN/UAS-5 was relegated to the role of back-up to the Project MICHIGAN scanners, and the main effort and emphasis toward obtaining infrared imagery were applied to these scanners. It is for these reasons and the fact that the Project MICHIGAN results were sufficiently good to perform an infrared evaluation that the results of the AN/UAS-5 are for the most part omitted. The exception to this is during the one situation in which the University of Michigan aircraft was grounded and thus unable to provide infrared coverage of Site II.

Finally, it might be mentioned here that the use of an operational AN/UAS-4 was deemed to be highly desirable. However, despite rigorous attempts on the part of USAEL, a Mohawk OV-1C could not be made available. The high degree of success of the imagery acquisition effort in Panama makes this fact truly regrettable.

B. SITE I

1. General Results

Thirty JC-47J daylight passes, 14 JC-47J night passes, and four U-1A daylight passes were flown over this site. At a 500-foot altitude, the vehicles were readily detected and identified by all sensors over the entire infrared region investigated and on all film types. Notable exceptions to this general statement are as follows:

(1) Identification on the infrared and SLAR imagery of the vehicles off the road is not possible without recourse to additional information.

(2) Identification on the infrared and SLAR imagery of the vehicles on the road as "probable vehicles" was possible by the interpreter only because of their location.

At a 500-foot altitude (1 : 3400), the entrenchments were detected and identified on all conventional photography. By way of the black and white and the black and white infrared, these entrenchments were also identified at 1000 feet (1 : 6800) but only barely detectable at 1500 feet (1 : 10, 200)*. The personnel in the short grass were identified as such on the larger 1 : 3400 scale color and color infrared films but were only detectable (not identifiable) on the black and white and the black and white infrared films at the two scales 1 : 3400 and 1 : 6800. At 1 : 10, 200, these personnel are not detectable. The firepots were detected at only the 500-foot altitude on the color and color infrared film (1 : 3400 scale) and black and white film (1 : 1000 scale); on the infrared scanner imagery they were detected at all altitudes tested, but not identified. The ambush site was detected on both the color and color infrared photography at the one scale tested (1 : 3400).

2. Comparative Sensor Cover

Figures 25 through 28 and 30 through 35 depict the comparative sensor cover of Site I provided by the three sensors, all imaging at 500 feet with the exception of the SLAR, which is optimized to operate at 1300 feet. The first of these 10, Figure 25, is a typical example of the coverage obtained with conventional black and white photography. This photography, a mosaic of Site I, taken with Plus-X film and a minus blue filter, is representative of the film-filter combination that is in common use in our reconnaissance activities today. The trucks can be seen in fair relief against the background of the short grass as well as the trucks on the road. The entrenchments can also be detected. Figure 26 is a black and white infrared photographic mosaic of Site I. The trucks off the road are now a little more detectable than they were in the black and white photograph of Figure 25.

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*It must be pointed out here that whereas conclusions are made concerning the detectability and identifiability of items at certain scales, no real attempt was made to determine the cutoff in detection and the cutoff in identification. Acquisition of these data would require another experiment and one which these tests were neither designed for nor meant to answer. In addition, optical magnifiers of 2 and 3 power were generally used by the interpreters; thus, the indicated scale in each case is generally meant only to provide information as to the scale of the originals from which the analysis was done. Consequently, any mention throughout this report relative to capabilities of conventional photography at a certain scale is meant to be illustrative rather than an attempt at defining scale limitations.

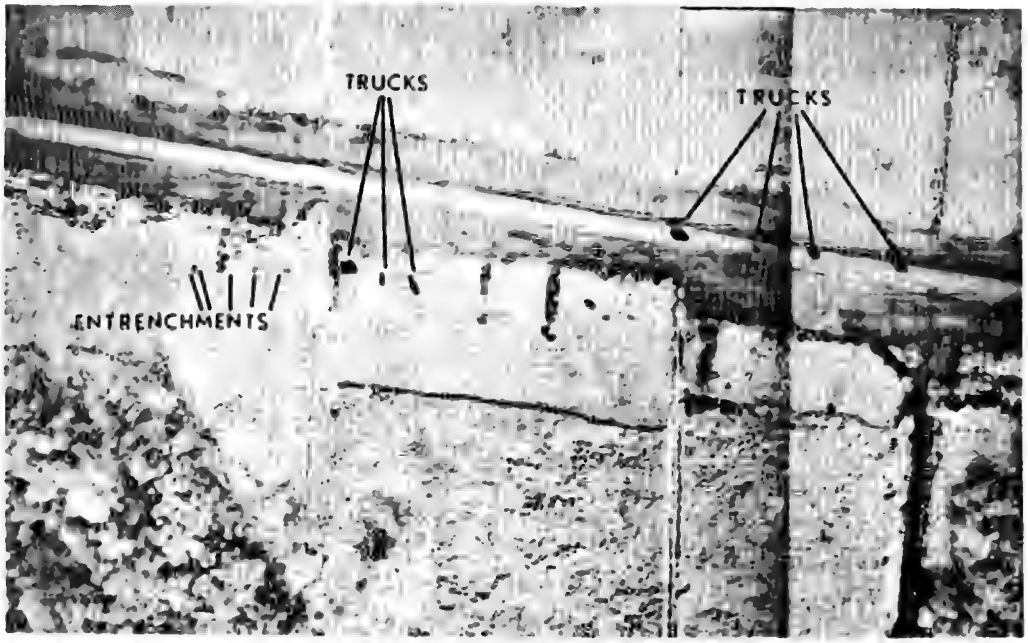

Figure 25. (U) Site I - KA-50A, Black and White, Minus Blue Filter

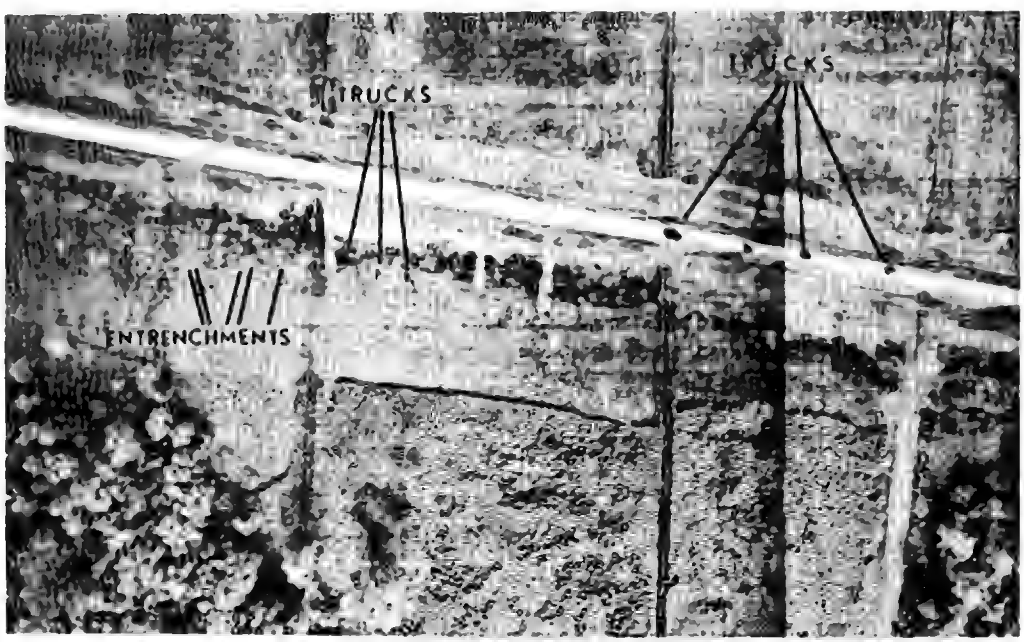

Figure 26. (U) Site I - KA-50A, Black and White Infrared

This fact is to a large extent due to the natural green vegetation against which the vehicles appear. The natural green now appears in a different tone because of the vegetation's infrared radiation to which this film is highly sensitive. The diggings are reasonably detectable here also but might escape detection in a rapid examination of the material, though certainly all the trucks would be readily seen. In Figure 27, an Ektachrome view of this site, one is able to clearly detect both configurations of vehicles; this photograph also presents the first inkling of other ground activity, as is relatively easily revealed by the white dots in the ambush position (the tee-shirts of men who removed their fatigue jackets), the white dots along the road (ground control personnel), and four of the six men in reclining positions in the short-grass area. The vehicles against the light background of the road are perhaps a little more easily detectable here than those against the grass background; though once detected, the vehicle type can be identified in each case.

Figure 28, a color infrared (Camouflage Detection) mosaic of this site, depicts the vegetation in one or another shade of red. In this figure, the vehicles are once again very readily detectable; now, however, more so (however negligible) against the grass than against the lighter background of the road. The white-shirted personnel are also perhaps even a little more detectable here than in Figure 27 as are the six men lying in the short grass. The machine gun positions of the ambush are here evidenced by the distinct gray spots caused by the trampling and killing of the vegetation in these areas. (Note the trampled, dead grass in this area shown in Figure 29). On very careful examination of the originals one can also now note the positions of the personnel, although the personnel themselves are not detectable in this situation. The diggings did not reveal themselves on this film as was initially expected, and the following possible explanation is made. The "dead" foliage which was used to camouflage the entrenchments and was expected to be the primary clue in revealing their presence was relatively fresh and still very infrared active. As a matter of fact, the camouflage itself is the clue that might be used in detecting these diggings in the color shot of Figure 27. Here, in the apparent haste to set up the camouflage, the bright green undersides

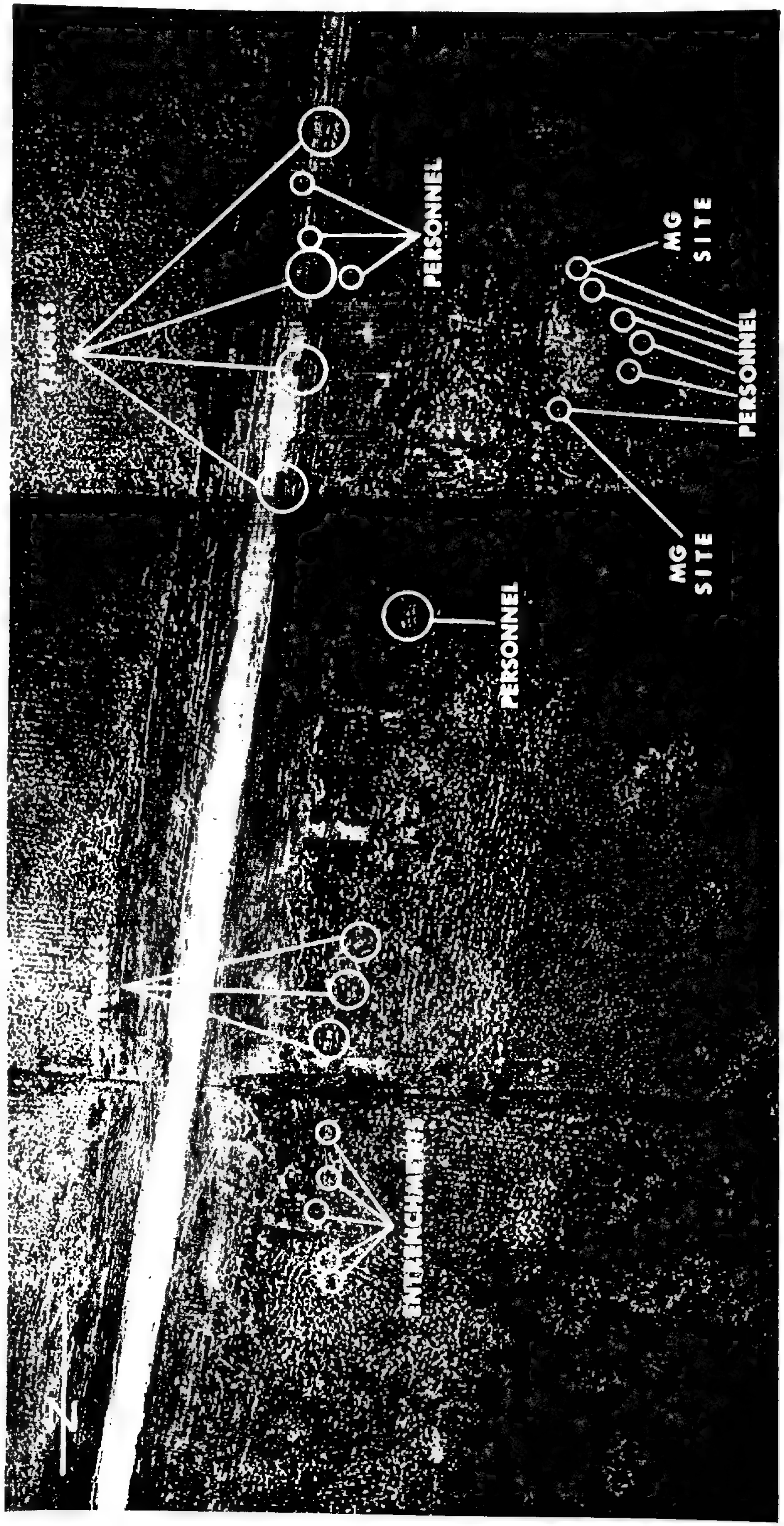

Figure 27. (U) Site I - KA-50A, Color (Ektachrome)

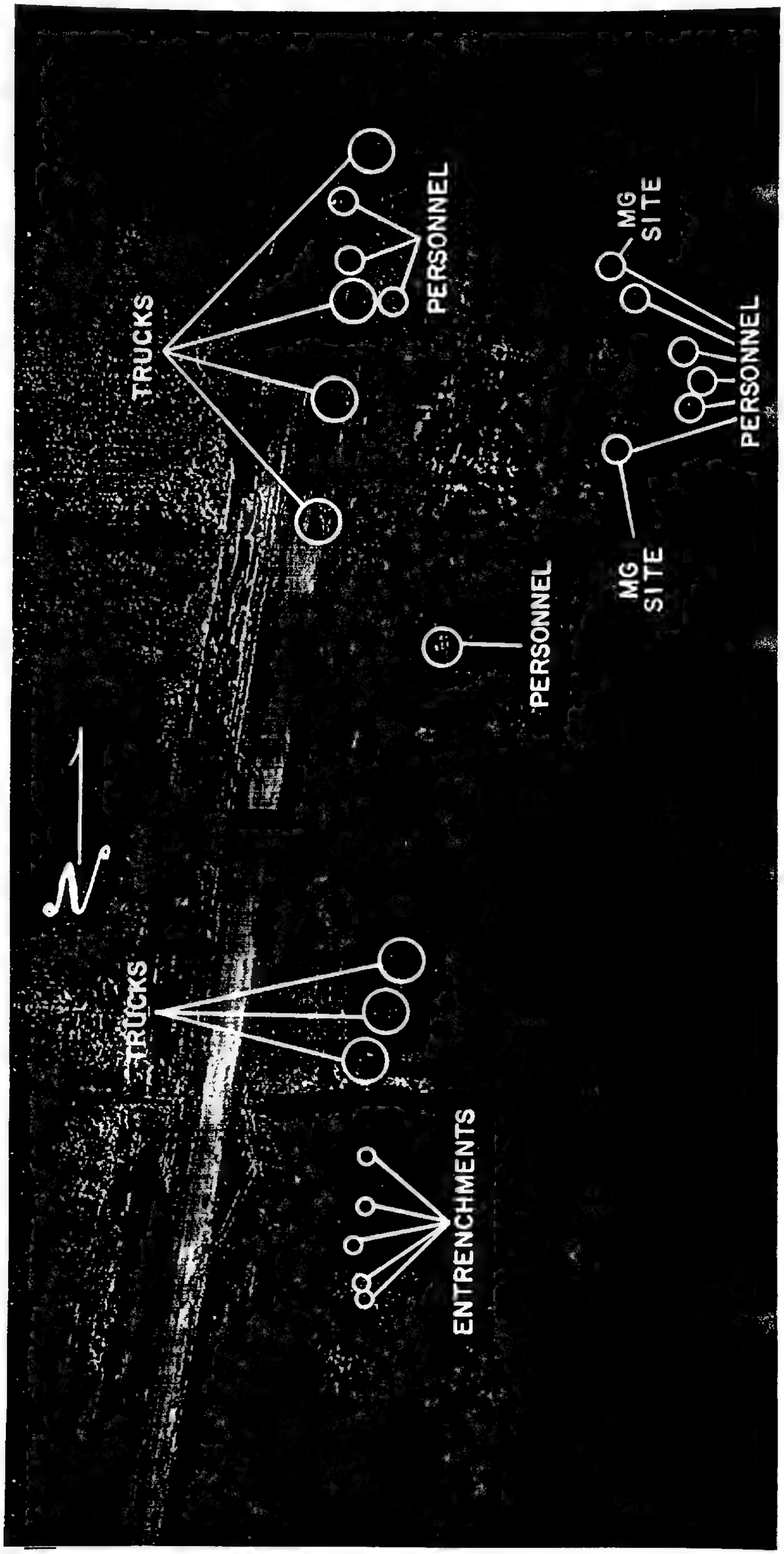

Figure 28. (U) Site I - KA-50A, Color Infrared

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Figure 29. (U) Ambush at Site I

of the leaves of the foliage were left exposed to aerial view and contrasted well with the other adjacent untampered-with vegetation. In Figure 28, in the last truck (a 2-1/2 ton) in line along the road, one can notice a little red blob in place of the brown blob of Figure 27. This bright red spot is obviously freshly cut vegetation. Figure 30 is a black and white mosaic of the same site without the minus blue filter and compares favorably with the view of Figure 25. Figure 31 is an Anscochrome view of this site taken under rather poor light conditions. Figure 32 is the AN/APQ-86 Side-Looking Airborne Radar view of the same scene, but includes a much larger area. Site I in this figure is generally confined to the area enclosed within the small rectangle where the vehicle radar returns show up clearly against the non-reflective road. The jungle vegetation is intangible as far as interest in counterinsurgency-type targets is concerned and as far as the vehicles themselves are concerned along any trail that is not open. This SLAR record typifies what is to be expected over this type of terrain with this type of radar. Figures 33 and 41, which cover the micron region from 1.0 to 5.5 and 8 to 13.5, yield a comparison of daytime infrared with conventional photography and SLAR over Site I. The second of these two figures, covering the micron region from 1.0 to 5.5, provides an excellent detection of all vehicles appearing as cold targets and of three distinct, easily resolvable firepots which appear as hot targets. The four partially camouflaged entrenchments are also relatively easily detectable. On Figure 33, which covers the 8.5 to 13.5 micron region, all vehicles are detectable, as are the three firepots; however, the entrenchments are not detectable. All detectable targets appear here hotter than their surroundings. (This phenomenon of hot and cold targets depends to a large extent on the background and on the spectral region used.)

From this comparative sensor coverage, the following generalizations might be made relative to the targets in their environment as they appeared at Site I. There is relatively little difference among the different films tested in their ability to detect and identify unobscured vehicles on a dirt road. Camouflage detection film provides a slight edge in detecting and identifying vehicles against a highly infrared active background. Without the daytime infrared scanner record, firepots

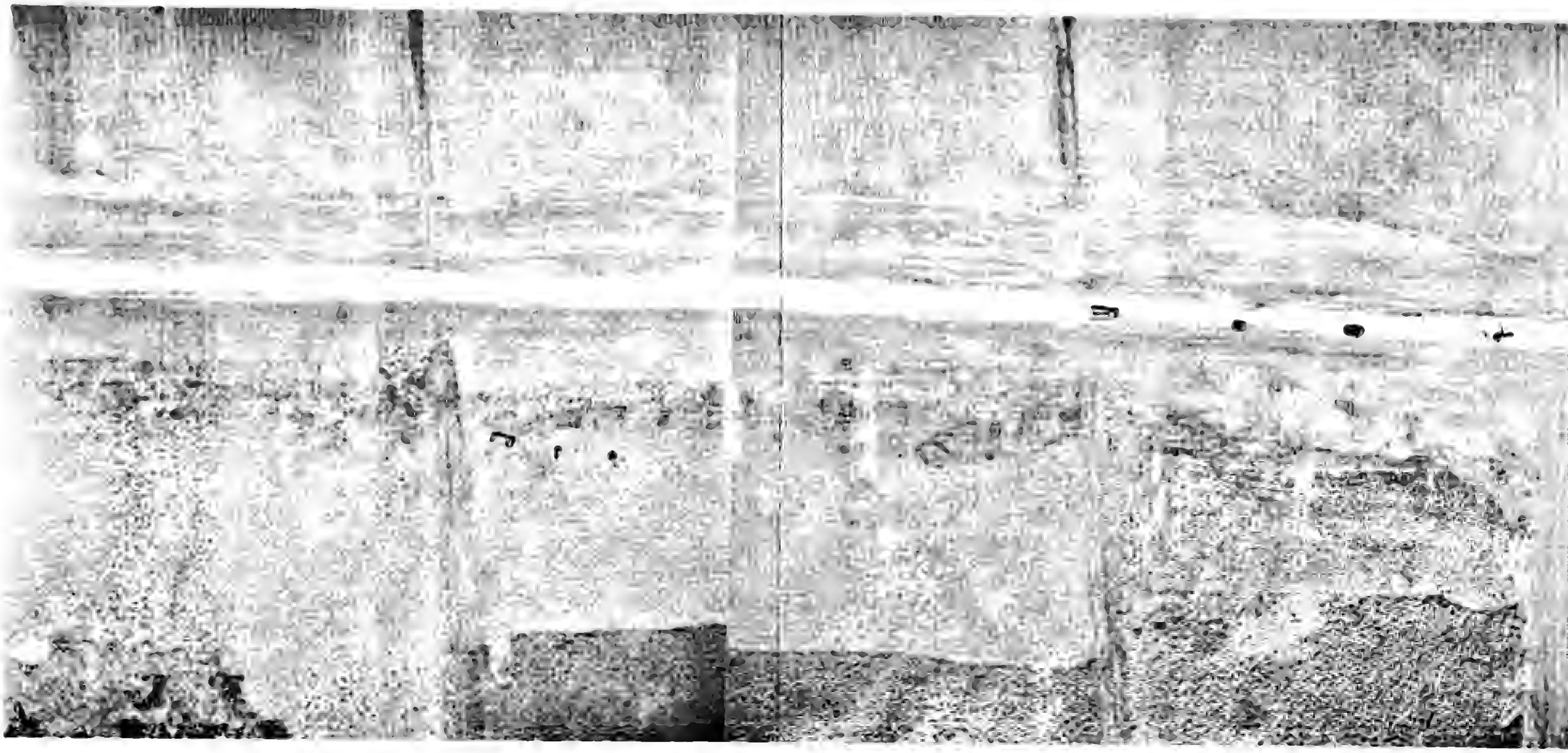

Figure 30. (U) Site I - KA-39, Black and White

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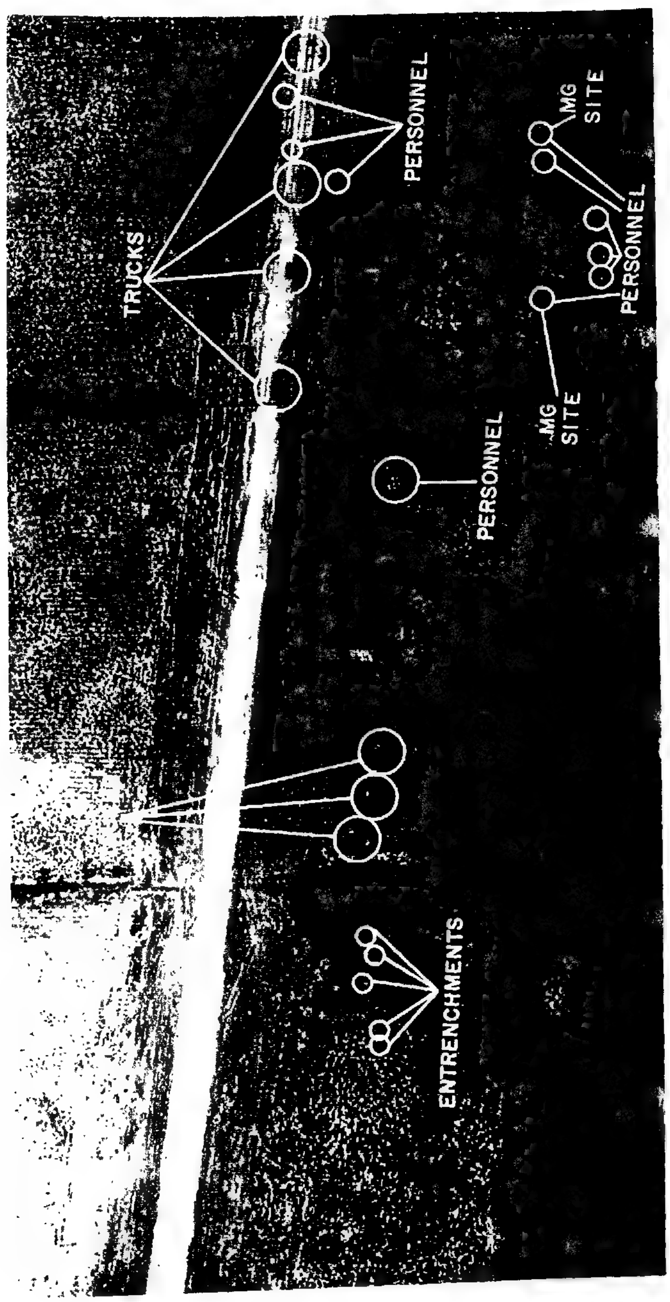

Figure 31. (U) Site I - KA-39, Color (Anscochrome)

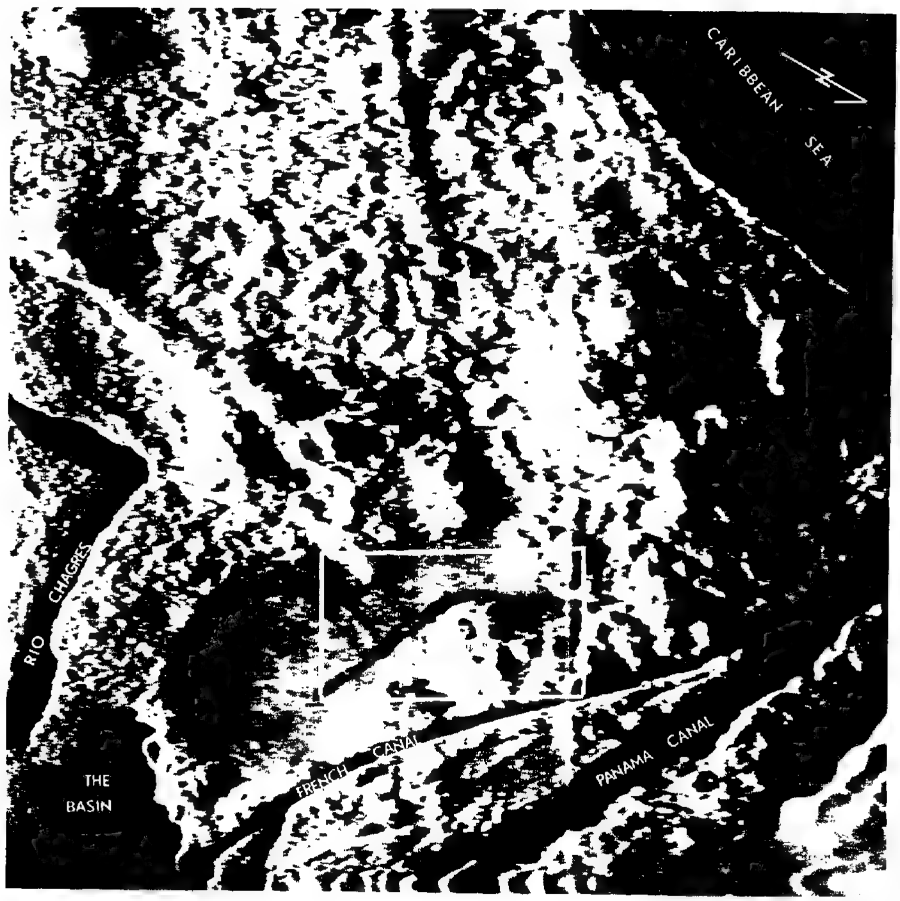

Figure 32. (C) AN/APQ-86 SLAR Imagery of Site I

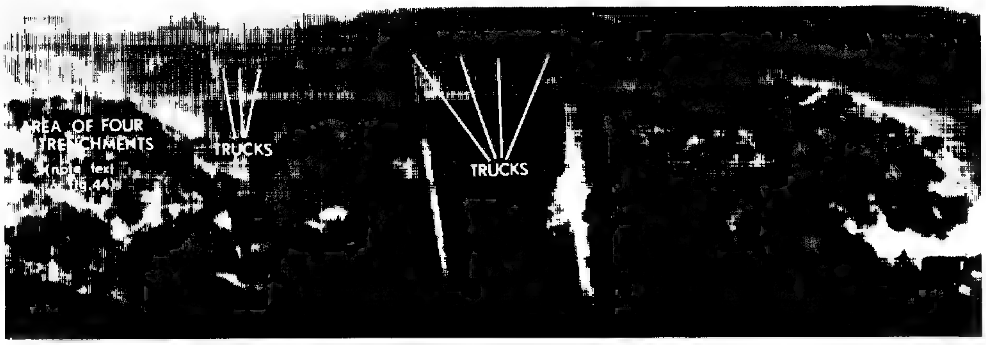

Figure 33. (C) Site I - D-2 Scanner, 8.5-13.5μ, Altitude 500 Feet, 141132 April 64

would go unnoted on all versions of the conventional photography; however, once detected on the infrared scanner record, they are subject to possible identification by stereoscopic viewing of the large-scale (1 : 1,000) black and white photography. The same is true to some extent in the case of the entrenchments. These, under most conditions of photographic coverage alone, would most likely go unobserved. However, once detected by way of the infrared scanner record, they can be identified. Personnel are detectable and identifiable as such on conventional photography at these scales only in those extreme cases where the appearance of an individual provides a sharp contrast to the surroundings. Color infrared provides some capability in detecting trampled, dead grass; however, little real capability is provided in detecting a small, short time-buildup (which is most typical) of an ambush site. Trails made through high grass by infiltrating guerrillas such as the trails simulated in Site I were not detectable by any methods tested.

A further comparison with infrared of this site might be made with Figures 34 and 36, which were obtained from an altitude of 1000 feet in the early morning predawn and represent the time at which the earth is at its coolest. The first of these two figures covers the 1 to 5.5 micron region, and in it can be seen all of the vehicles. The two engine-off vehicles on the road appear as very faint cold returns (on the originals). The firepots are clearly discernible and readily resolvable. In the 8.5 to 13.5 micron region represented by Figure 36, we observe

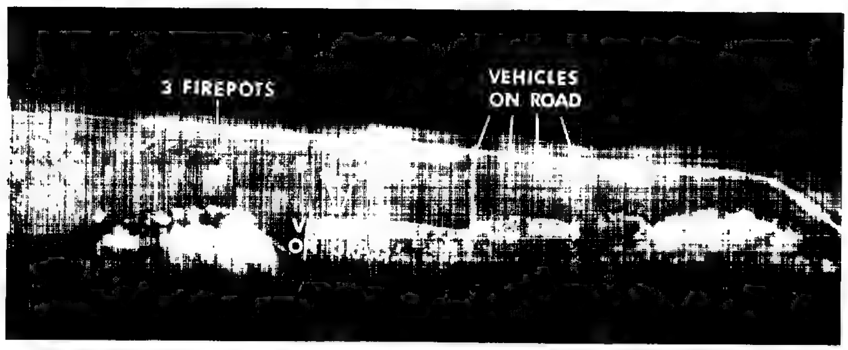

Figure 34. (C) Site I - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 140433 April 64

Figure 35. (C) Site I - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 140433 April 64

essentially the same situations as in the previous figure relative to the vehicles and the firepots.

3. Infrared Evaluation

A total of 12 passes were flown by the Project MICHIGAN aircraft over this target

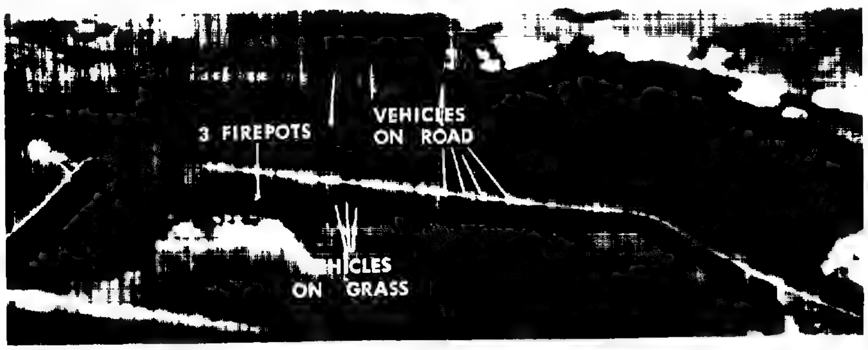

Figure 36. (C) Site I - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 140454 April 64

site. Five of these passes were flown between 0410 and 0500 hours; the other seven were flown the same day between 1115 and 1140 hours. The predawn missions were flown after a night of intermittent rain under a scattered-clouds condition. Thus, both the ground and target components were wet. The ground and vehicles were still wet during the daylight runs, which were made under partly sunny conditions.

The M-2 scanner produced acceptable imagery on each of the 12 passes, while the D-2 scanner malfunctioned on two passes. In the predawn mission, all passes were flown at 1000 feet. The M-2 scanner was equipped with an unfiltered InSb detector (1.0 - 5.5μ), and the D-2 with an 8.5 - 13.5μ Ge:Hg detector. Interpretation of the imagery negatives from these passes shows detectable signatures from all of the hot-engine vehicles for each pass by both scanners. The off-road 2-1/2 ton vehicle at ambient temperature also shows as a warm target on all of the imagery. While not detectable on D-2 imagery, the ambient temperature sedan* on the road shows as a colder-than-road-surface target on the short-wavelength

*While not part of the controlled situation, this vehicle, used by the ground truth team, was parked on the road about 500 feet north of the Carryall during some of the runs over this site. Its position is annotated in Figures 39 and 43.

M-2 imagery. The three firepots also appeared as strong signals on all of the passes with both scanners, while the trenches were not apparent in any of this predawn imagery. Figures 34 and 35 show representative samples of the short- and long-wavelength imagery from this predawn mission. Although the target background contrast has been somewhat reduced in printing, the vehicle and target signatures are quite evident, particularly with the M-2 scanner. Note the scale difference between the strip maps from the two scanners, with the larger scale of the M-2 affording increased target detectability and the smaller scale of the D-2 giving more general orientation and terrain information.

In the daylight mission over Site I, the sensors were again the M-2 and the D-2. The D-2 was operated at 8.5 - 13.5μ during all seven passes, six of which produced acceptable imagery; the M-2 scanner, on the other hand, was operated unfiltered (1.0 - 5.5μ) on three passes, filtered to 2.0 - 2.6μ on two, and to 4.5 - 5.5μ on two, with acceptable imagery resulting from all seven passes. In addition to these wavelength variations, flight altitude was varied with four passes at 1000 feet and three at 500 feet. Samples of each wavelength condition at each altitude were obtained. With the M-2 scanner, all of the vehicles were detected on all passes, with the exception of the sedan, which was detected only twice. The four trenches produced detectable signatures on each of the three 1.0 - 5.5μ passes and on one of the two 2.0 - 2.6μ passes with the M-2 scanner. As expected, the firepots provided strong signals on all passes. With the D-2 scanner (8.5 - 13.5μ), all vehicles including the sedan were detected on all six passes. The trenches, however, were not evident in any of the long-wavelength imagery.

Figures 37 through 43 present samples of the daylight imagery of Target Site I. Figures 37 through 40 show examples of the four wavelength intervals used at 1000 feet, while Figures 41 through 43 contain three wavelength samples obtained at a 500-foot altitude. The short-wavelength imagery of Figures 37 and 38 show the predominance of reflected solar energy in the sensor output to the extent that even the engine-running vehicles appear colder than their background because of the lower reflectance of the vehicles. (Note the "cold" trench signals in Figure 37.) In comparison, the longer-wavelength imagery of Figures 39 and 40 more

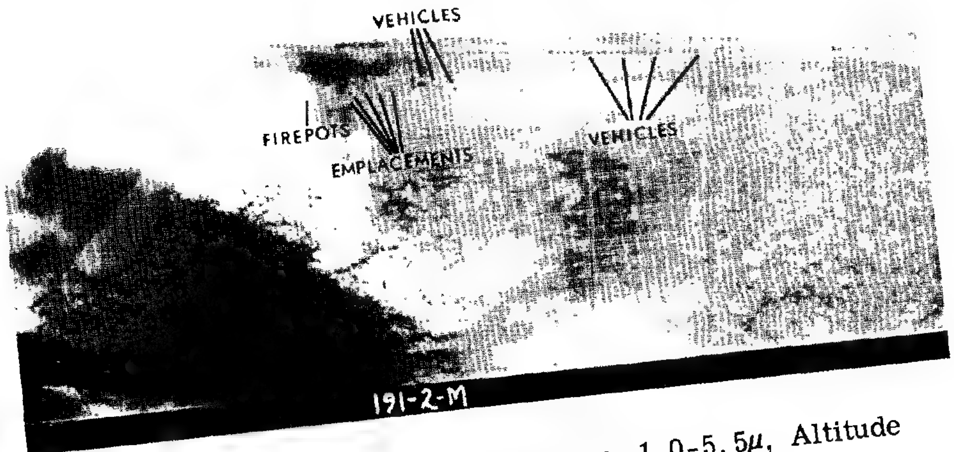

Figure 37. (C) Site I - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 141117 April 64

Figure 38. (C) Site I - M-2 Scanner, 2.0-2.6μ, Altitude 1000 Feet, 141123 April 64

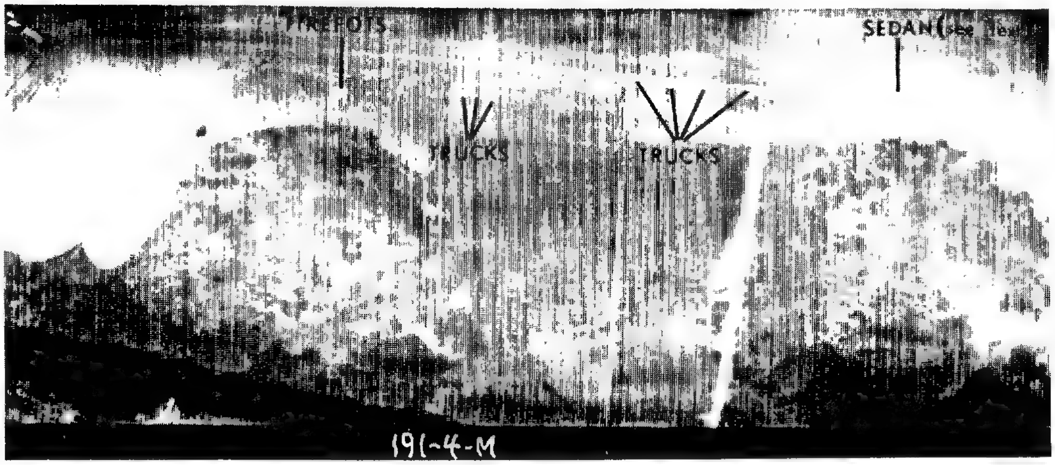

Figure 39. (C) Site I - M-2 Scanner, 4.5-5.5μ, Altitude 1000 Feet, 141129 April 64

Figure 40. (C) Site I - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 141123 April 64

correctly represent the thermal conditions of Site I. Although the entrenchments are no longer apparent, all vehicles come through as warmer than background. Figures 41 through 43 show a similar wavelength effect at a flight altitude of 500 feet. Comparison of Figures 37 through 43 shows that little difference other than image size exists between the two altitude samples. The relative contrasts of the several target components at a given wavelength are relatively constant across the two altitude samples.

C. SITE II

1. General Results

Twenty-three JC-47J daylight passes, 23 JC-47J night passes, and four U-1A daylight passes were flown over this site. As can be seen from Chart 3, the AN/UAS-5 provided the only infrared coverage of this site. Of the rather meager infrared coverage obtained by way of the AN/UAS-5, the only consistent returns were provided by the firepot and this only at altitudes under 1000 feet. All SLAR passes (4) over this site either did not cover the area (1) or gave no target returns (3). In one of these latter three cases there was an equipment malfunction. In general, the motorboat and the docked cayuca were readily detected and identified on the photography; however, the cayuca which was partially concealed went completely undetected at all altitudes on all passes with both optical and infrared. All but one of the seven vehicles were detected at 500 feet with black and white photography. Of those detected, four are identifiable. Detection and identification deteriorated rapidly above 500 feet on both optical and infrared.

2. Comparative Sensor Cover

A good comparison between infrared and photographic coverage of this site and among the different photographic films that were available is difficult because of the limited amount of coverage obtained over this site by the infrared scanner and cameras. Figures 44 and 45 are typical examples of the infrared scanner and black and white photographic coverage obtained over this site. No significant difference in detection or identifiability was noted between the faster but more grainy black and white Tri-X and the black and white Plus-X films.

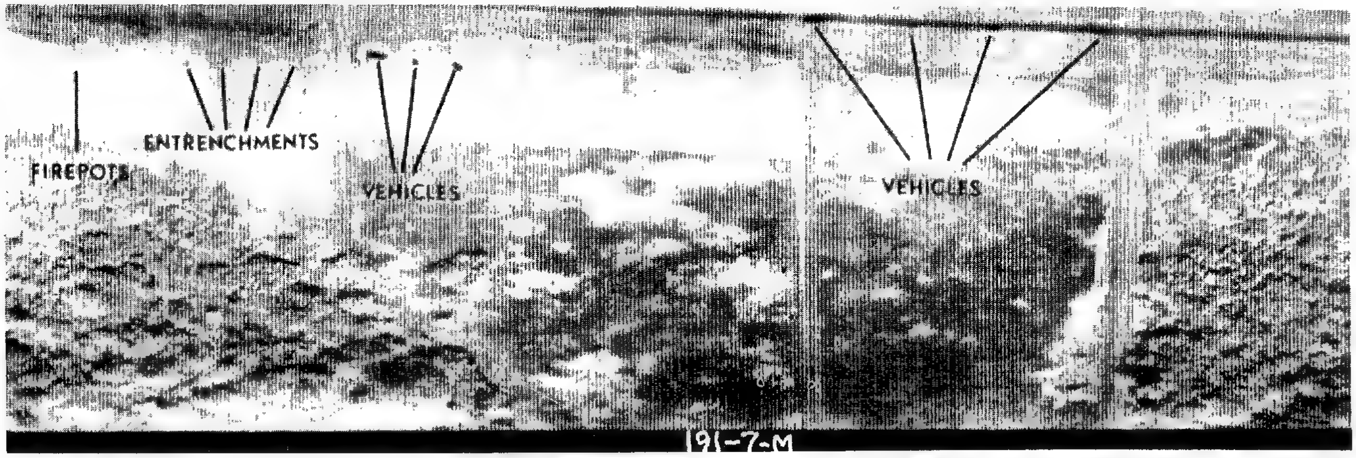

Figure 41. (C) Site I - M-2 Scanner, 1.0-5.5μ, Altitude 500 Feet, 141140 April 64

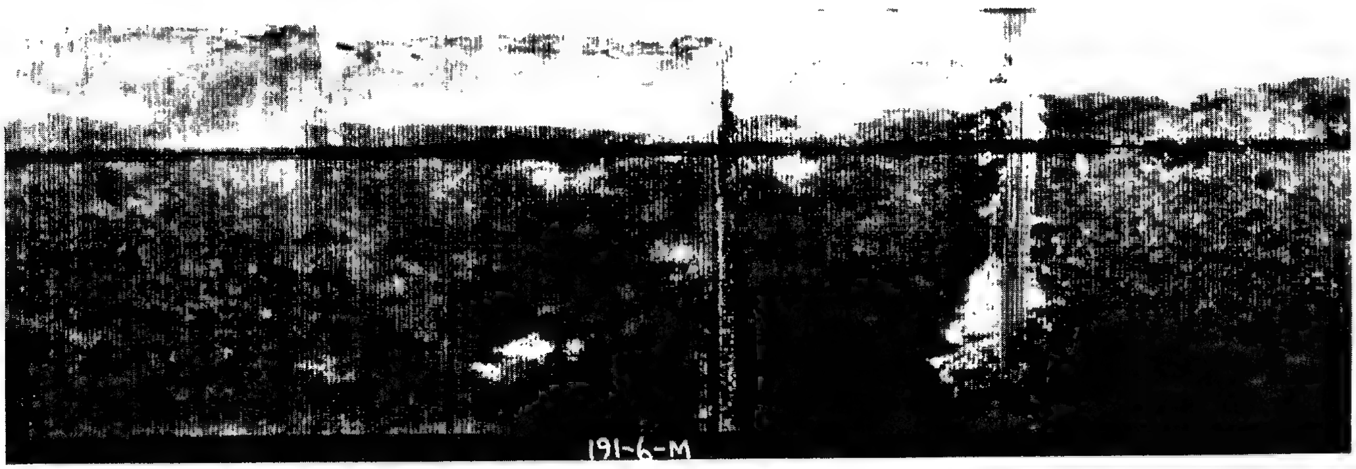

Figure 42. (C) Site I - M-2 Scanner, 2.0-2.6μ, Altitude 500 Feet, 141137 April 64

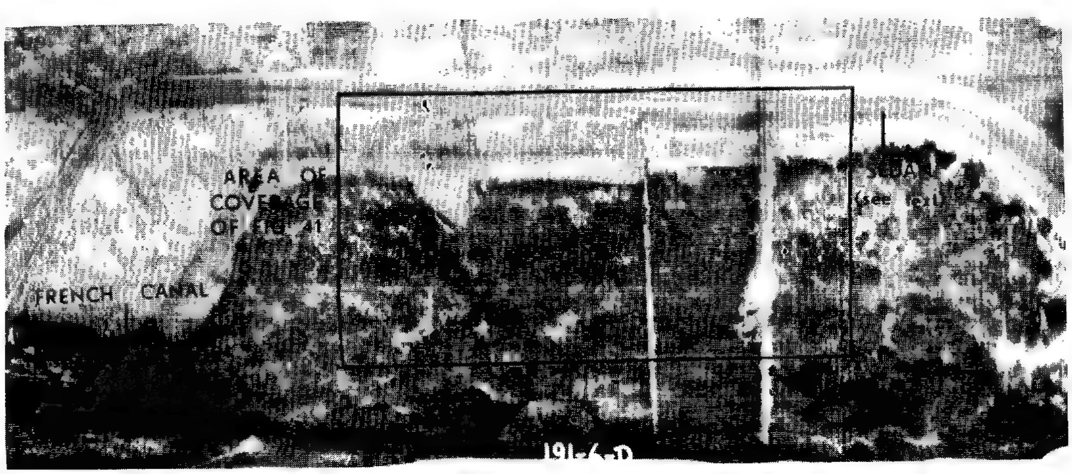

Figure 43. (C) Site I - D-2 Scanner, 8.5-13.5μ, Altitude 500 Feet, 141137 April 64

Figure 44. (U) Site II - UAS-5, 1.05-5.5μ, Altitude 1250 Feet, 211920 April 64

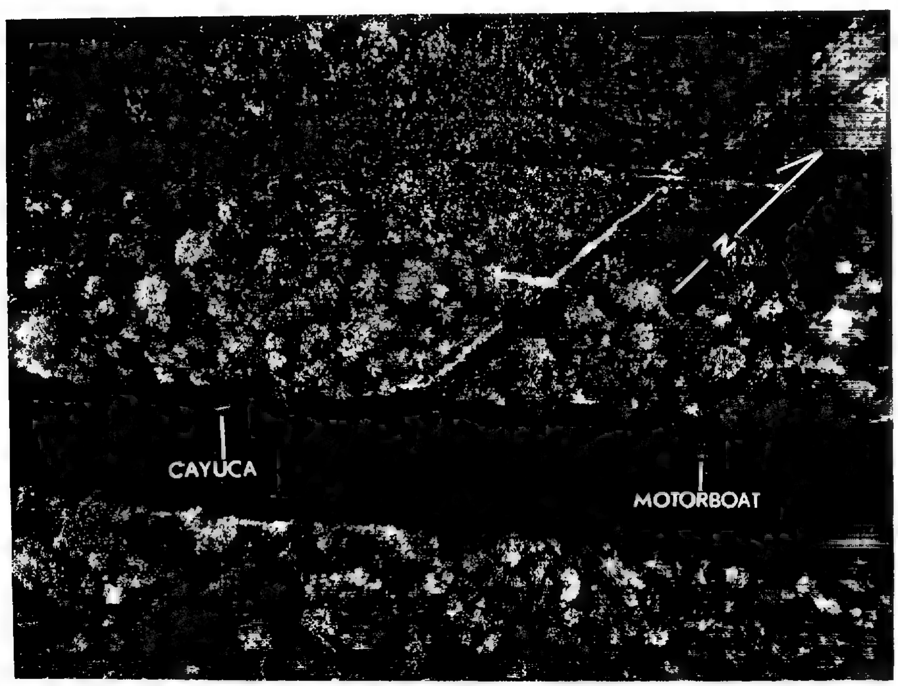

Figure 45. (U) Site II - KA-50A, Black and White, WR G12

3. Infrared Evaluation

The entire infrared coverage of this site was obtained with the AN/UAS-5. The firepot at this site was covered a total of 28 times; detection occurred a total of 12 times, representing 43 percent of the possible total. There were a total of nine vehicle returns out of a possible total of 196 for a percentage of just under five percent. These two target types were the only items detectable at this site, and further conclusions relative to infrared capability over an area similar to this cannot be drawn from the limited infrared data obtained.

D. SITES III AND IV

1. General Results

Twenty JC-47J daylight passes, 33 JC-47J night passes, and two U-1A daylight passes were flown over Site III. Twenty JC-47J daylight passes, 29 JC-47J night passes, and one U-1A daylight pass were flown over Site IV. Because of the heavy canopy cover over Site III, no optical detection of the firepots was possible. Detection of these firepots was made only by the infrared sensor, which seemed to indicate some penetration of the heavy canopy. In addition, detection of these firepots seemed to depend more on the angle of view and density of canopy than on the altitude or the diameter of the firepot over the variations of these two parameters explored at this site. Of the six firepots at Site III, two were not detected on any of the missions over the site; however, the present state-of-the-art in infrared interpretation did not allow for positive identification of any of those that were detected.

The firepot used for reference purposes at Site IV was situated in a clearing and generally in direct line of sight of the reconnaissance aircraft. The firepot appeared, as expected, consistently on the infrared record of this site. Its use as a reference point, however, proved to be not needed as the majority of the vehicles were consistently imaged through the rather light canopy cover by the infrared sensors. The cameras repeatedly detected at least one or two different vehicles on each pass, depending on the camera's angle of view each time. Identification of the detected vehicles, however, proved in most cases to be extremely difficult

due at all times to partial concealment of the vehicles. Only one SLAR mission was attempted over this site, and on neither of the two SLAR passes was any vehicle imaged through any of the holes in the canopy.

2. Comparative Sensor Cover

Figures 46 through 49 depict the comparative sensor cover of Sites III and IV. In Figure 46, which is a camouflage detection view of Site IV, it can be noted that the lead vehicle (the one closest to the firepot) stands out in substantially better relief from the surrounding vegetation than in Figure 47, a black and white infrared view of the same scene. This permits one to better detect the vehicle's presence as well as to identify its type. Figures 48 and 49 represent typical results obtained over these sites at night with infrared over the range from 1.0 to 5.5μ and 8.5 to 13.5μ respectively.

This site is a good example of the advantages to be gained through multisensor coverage. Although under the best conditions only three vehicles were detected on the photography (covering black and white, black and white infrared, and color infrared film), seven returns were detected by the infrared scanner. From the configuration of the returns on the infrared record (seven returns 100 feet apart), the location (on the road), and with three of the returns identified previously as vehicles on the photography, the image interpreter would identify this as a seven-vehicle convoy.

3. Infrared Evaluation

A total of 17 passes were flown by the Project MICHIGAN aircraft over these target sites. All of these flights were flown on the same day; five were between 0417 and 0505 hours, seven between 0803 and 0841 hours, and five from 2018 to 2057 hours. The predawn missions were flown under a low, scattered-clouds condition with the ground saturated from rain shortly before the mission. The daylight morning mission was associated with a low, overcast condition with heavy, intermittent showers occurring in the target area during some of the data acquisition passes. The evening mission, while free from rain, was flown under a low-scattered overcast with saturated ground conditions.

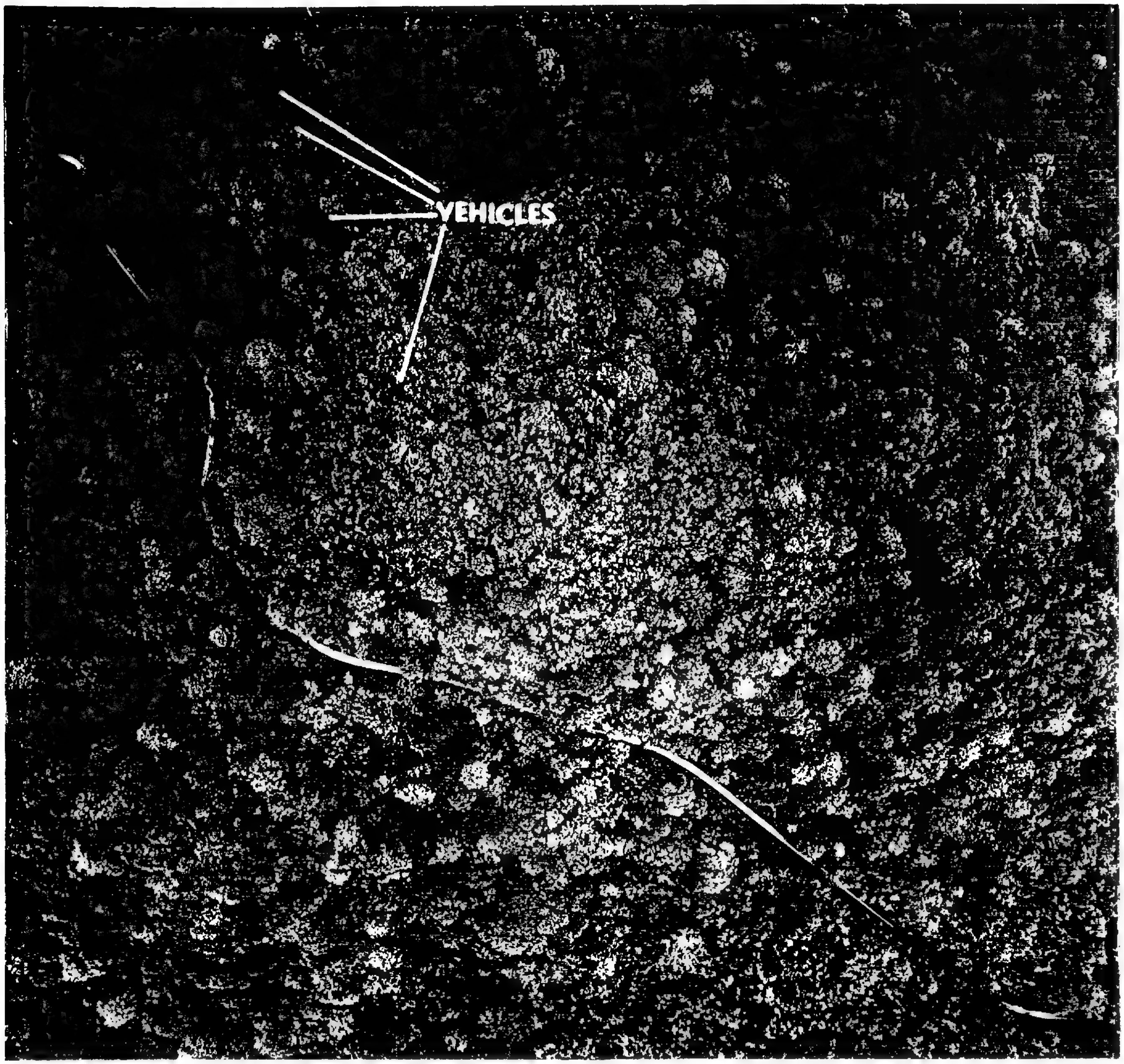

Figure 46. (U) Site IV - KA-50A, Color Infrared

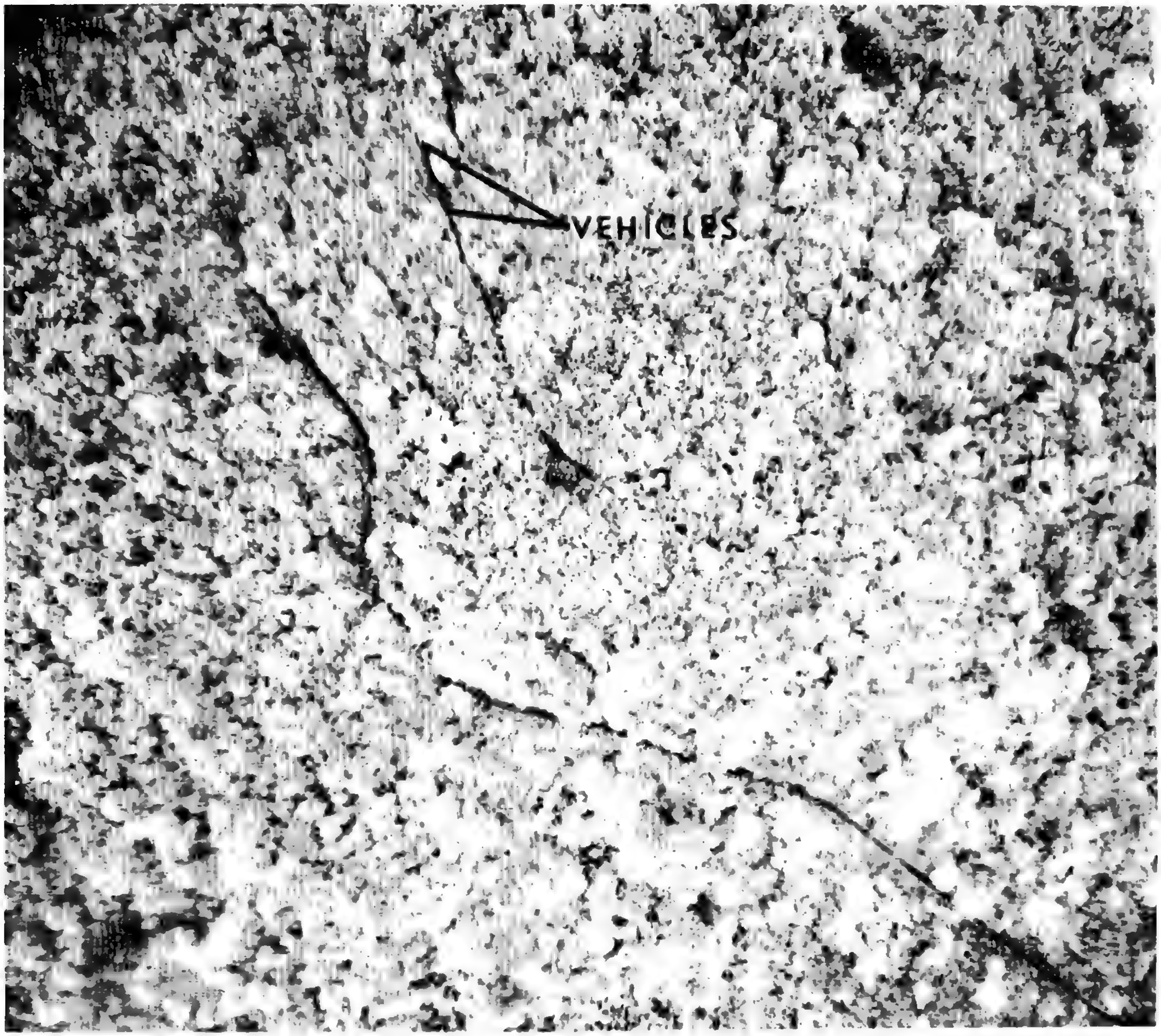

Figure 47. (U) Site IV - KA-50A, Black and White Infrared

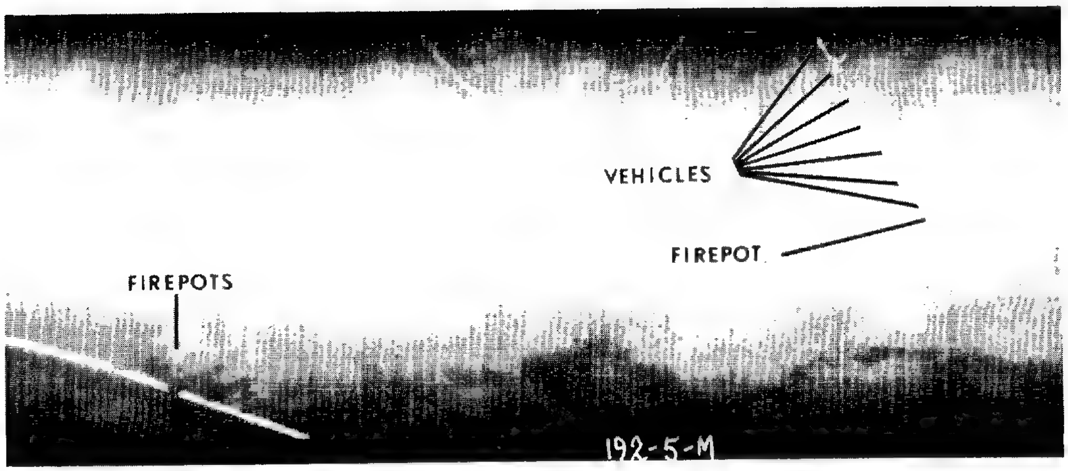

Figure 48. (C) Sites III and IV - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 150417 April 64

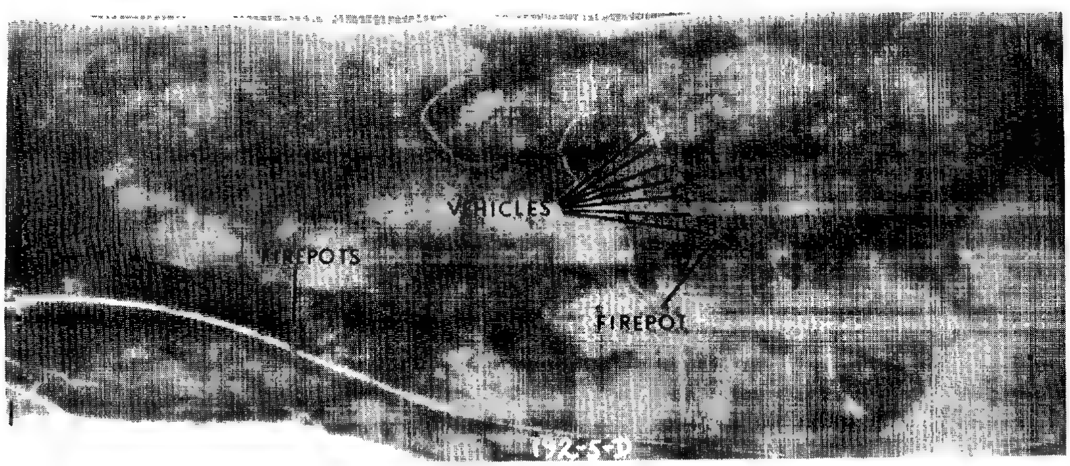

Figure 49. (C) Sites III and IV - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 150417 April 64

The sensor configuration on all passes over these sites was again the M-2 and the D-2 scanners. In the predawn missions, all five passes were flown at 1000 feet. The M-2 scanner was equipped with an unfiltered InSb detector (1.0 - 5.5μ), and the D-2 with an 8.5 - 13.5μ Ge:Hg detector. Only four of the five attempted passes produced acceptable imagery, since the first pass of the mission was off-line and missed both target sites. At Site III, no personnel were detected on any of these predawn passes. Even the firepots proved difficult because of the dense forest canopy under which they were emplaced. Of the total of 48 possible detections (6 pots x 4 passes x 2 scanners), only 9 detections were made. Eight of these were with the short-wavelength M-2 scanner. The appearance of these firepots is shown in the left side of the imagery samples in Figures 48 and 49.

Detections during this predawn mission were considerably better at Target Site IV. All vehicles and the firepot are detectable on all passes with the 1.0 - 5.5μ M-2 imagery. Similar results were obtained with the long-wavelength D-2, except that the engine-off 3/4-ton truck was not detected on two of the four acceptable passes. The right side of the imagery samples in Figures 48 and 49 shows the appearance of this simulated road patrol in the two wavelength regions used.

In the daylight mission over Sites III and IV, the sensors were again the M-2 and the D-2. The D-2 was operated at 8.5 - 13.5μ during all seven passes; only three passes produced acceptable imagery because of equipment problems. The M-2 scanner was operated unfiltered (1.0 - 5.5μ) on three passes (with two acceptable), filtered to 2.0 - 2.6μ on two passes, and filtered to 4.5 - 5.5μ on two passes. In addition to these wavelength variations, flight altitude was varied with three passes at 1000 feet and four passes at 500 feet. While acceptable imagery was obtained in all three wavelength regions at both altitudes with the M-2, malfunctions with the D-2 resulted in long-wavelength imagery only at the 1000-foot flight altitude.

With the Site III firepots, the M-2 scanner provided 10 detectable signatures out of a possible total of 36 (6 pots x 6 passes). Seven of these 10 detections were made at the 1000-foot altitude, with three each on the 2.0 - 2.6μ and the 4.5 - 5.5μ imagery and only one on the 1.0 - 5.5μ imagery. The three passes with the D-2 scanner produced 3 firepot detections out of a possible 18 (6 pots x 3 passes). The

left-side portions of the imagery samples in Figures 50 through 53 illustrate the appearance of the Site III firepots at the four wavelengths used with a flight altitude of 1000 feet. Note the heavy striation in Figures 51 and 52 reflecting the low signal/noise ratio obtained with these narrow band scans. Figures 54 through 56 illustrate the coverage at 500 feet as a function of wavelength. Note the particularly poor quality of the 2.0 - 2.6μ pass, which was made during heavy rainfall in the target area.

The daylight mission over Site IV produced considerably fewer detections than did the predawn mission. While the firepot is detectable on the imagery from all six of the M-2 passes, the vehicles proved to be more elusive. At the 1000-foot altitude, illustrated in Figures 50 through 53, all six of the engine-on vehicles were detected at 4.5 - 5.5μ, while only two were evident on the 2.0 - 2.6μ imagery and three on the 1.0 - 5.5μ pass. The 8.5 - 13.5μ D-2 scanner provided a somewhat better detection score at 1000 feet, with 13 detections of the engines-on vehicles of a possible 18 (6 vehicles x 3 passes). At the lower altitude, difficulty was experienced in centering the flight line to obtain full coverage of Site IV with the M-2 scanner. Thus, the carry-all and the 2-1/2 ton vehicle at the south end of the convoy target do not appear on the 500-foot imagery. Figures 54 through 56 are illustrative of the imagery acquired during the 500-foot mission. With the vehicles covered by the imagery, a total of five detections out of a possible 15 (5 vehicles x 3 passes) were obtained, with three of these acquired with the 4.5 - 5.5μ wavelength scanner. With the 1.0 - 5.5μ imagery, the scanner response to the predominant reflected skylight energy off the canopy served to obscure the vehicle signals, while the poor showing of the 2.0 - 2.6μ region is attributed to the rain that fell during the run.

With the evening mission, detections at both Sites III and IV increased, largely due to improved weather conditions. The low overcast and intermittent rain of the daylight mission had given way to a rain-free, scattered-cloud condition. A total of five passes were made over the target sites at an altitude of 1000 feet with both scanners producing acceptable imagery on all passes. The M-2 scanner was operated at 1.0 - 5.5μ , and the D-2 at 8.5 - 13.5μ . With Site III, the M-2

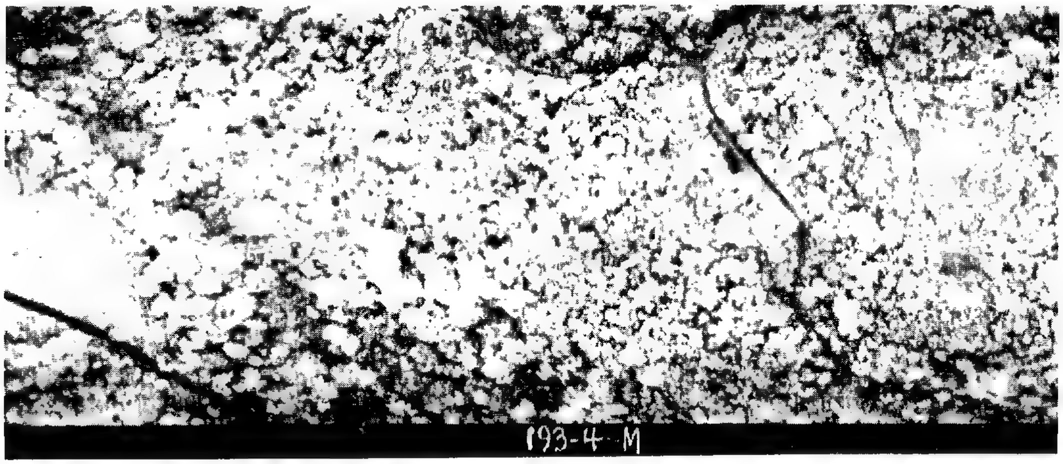

Figure 50. (C) Sites III and IV - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 150817 April 64

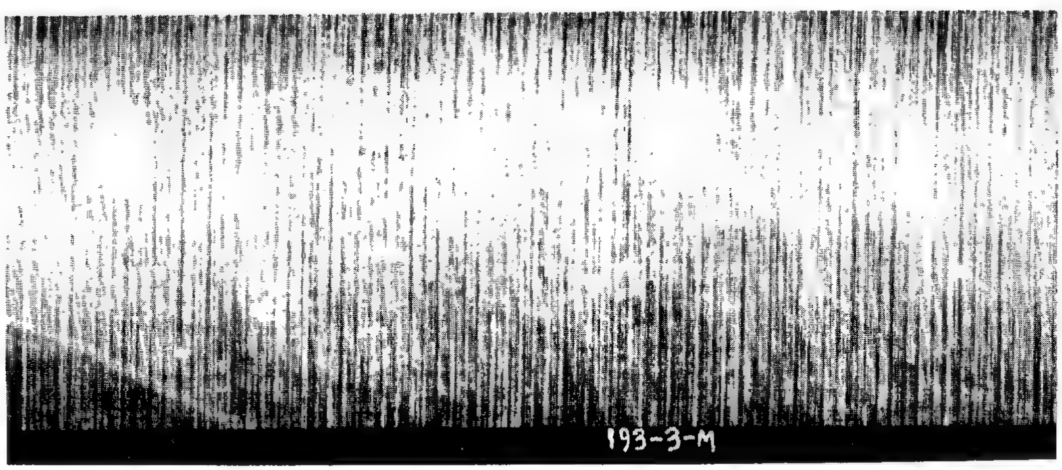

Figure 51. (C) Sites III and IV - M-2 Scanner, 2.0-2.6μ, Altitude 1000 Feet, 150810 April 64

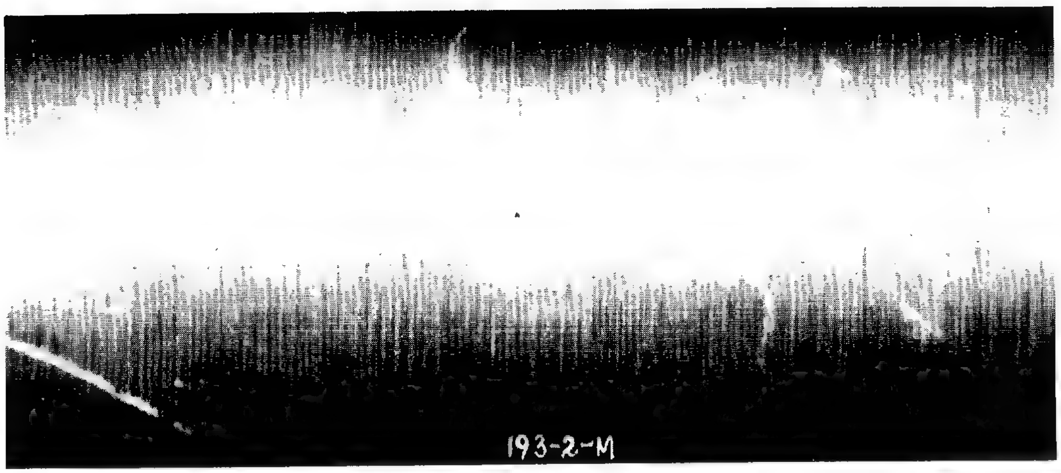

Figure 52. (C) Sites III and IV - M-2 Scanner, 4.5-5.5μ, Altitude 1000 Feet, 150803 April 64

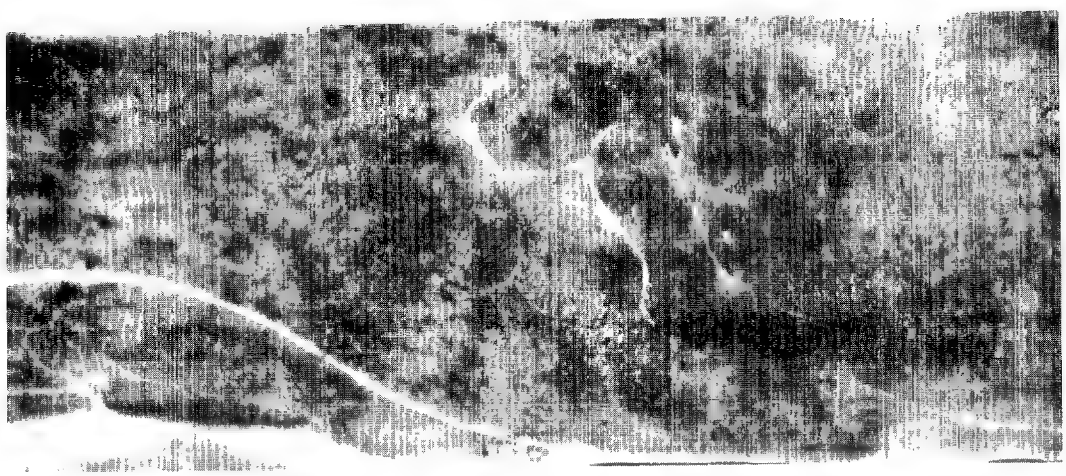

Figure 53. (C) Sites III and IV - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 150810 April 64

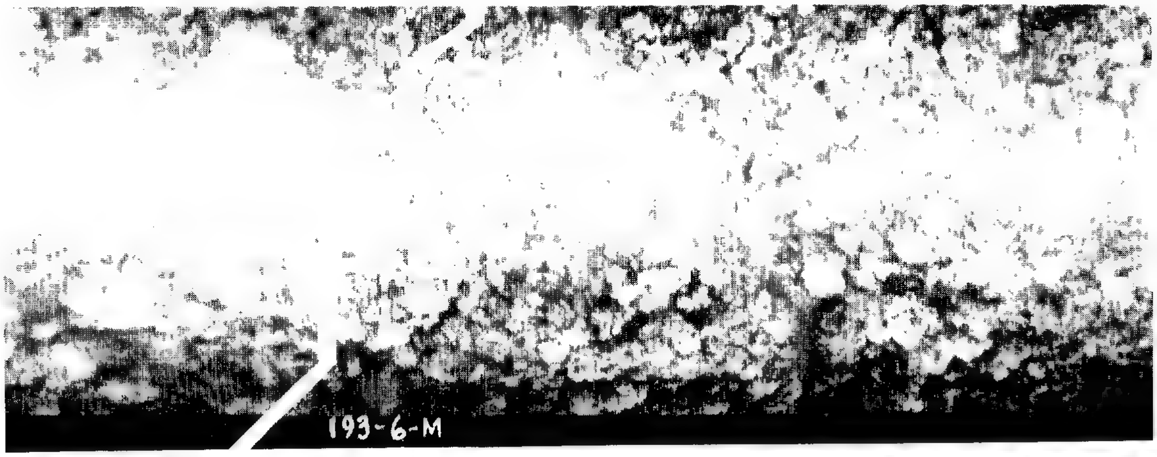

Figure 54. (C) Sites III and IV - M-2 Scanner, 1.0-5.5μ, Altitude 500 Feet, 150829 April 64

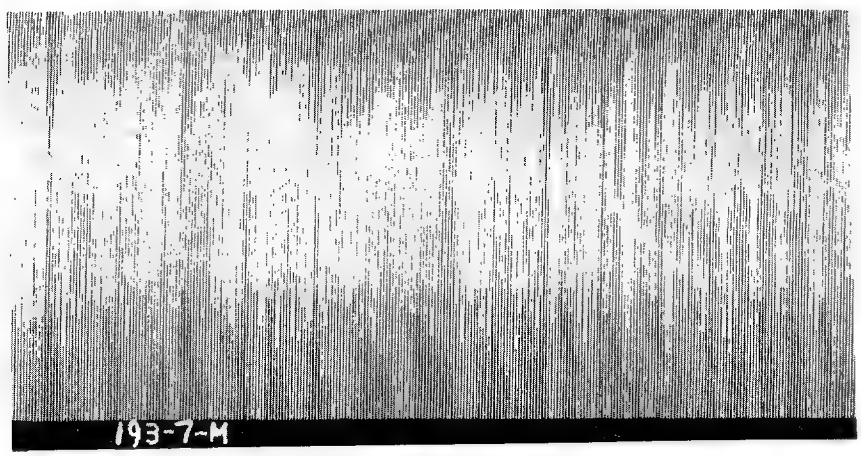

Figure 55. (C) Sites III and IV - M-2 Scanner, 2.0-2.6μ, Altitide 500 Feet, 150835 April 64

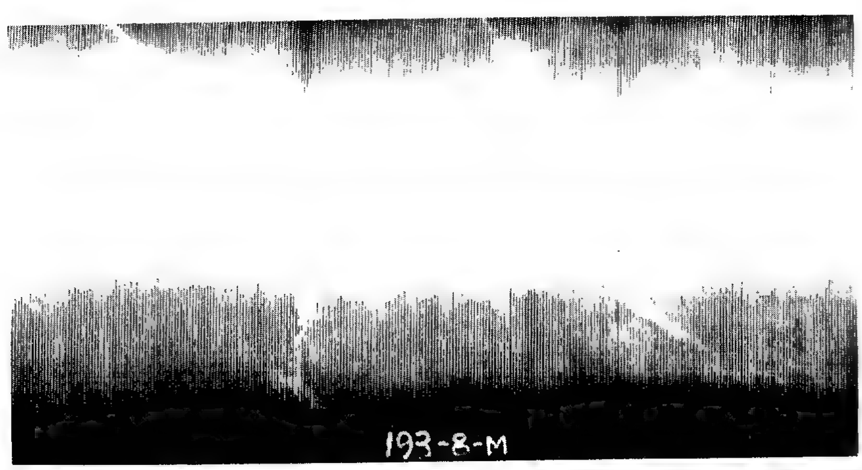

Figure 56. (C) Sites III and IV - M-2 Scanner, 4.5-5.5μ, Altitude 500 Feet, 150841 April 64

provided 11 firepot detections of a possible total of 30 (6 pots x 5 passes), and the long-wavelength D-2 provided 6 detections. At Site IV, the firepot was detected by both scanners on all passes. Including the engine-off 3/4-ton truck at the north end of the vehicle line, 35 detections were possible (7 vehicles x 5 passes) with each scanner. With the short-wavelength M-2 scanner, 30 of the 35 possible detections were made. The D-2 scanner provided a total of 29 detections. The appearance of the imagery collected during the evening missions over Sites III and IV is illustrated in Figures 57 and 58.

Several general observations may be made from the missions over Sites III and IV. The most striking result was that much more favorable detection data were obtained at predawn and post-sunset compared to that from the daylight mission. While this time-of-day effect is tempered by the unfavorable weather during the daylight mission, it would be predicted that the relatively small intense heat sources represented by operating engines and firepots should be more detectable under circumstances in which terrain and vegetation background energy is suppressed, a condition which exists in non-daylight hours. This relative energy consideration also explains the generally better detection results of 4.5 - 5.5μ and 8.5 - 13.5μ bands under daylight conditions. Reconnaissance at shorter wavelengths results in recording of predominantly reflected solar and skylight energy from vegetation and terrain, to the detriment of contrast between the small hot targets of interest and their surroundings.

E. SITE V

1. Infrared Evaluation

A total of 27 passes were made over Site V. The M-2 scanner provided acceptable imagery on all passes, and the D-2 malfunctioned on three passes. On five of the passes, only 11 of the 14 pots had been lighted. Thus, the maximum possible pot detections for the M-2 scanner was 363 (22 passes x 14 pots plus 5 passes x 11 pots); the maximum possible detections with the D-2 was 321 (19 passes x 14 pots plus 5 passes x 11 pots). Of the 363 possible detections

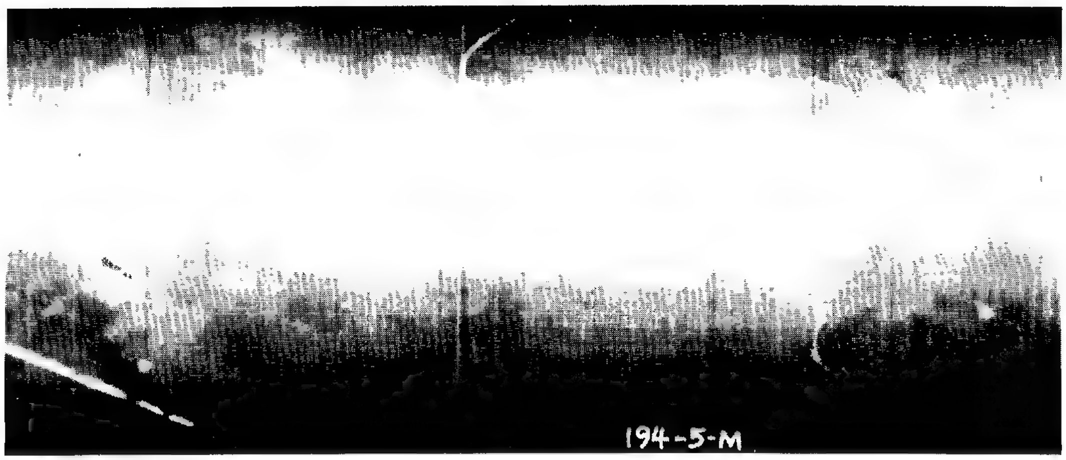

Figure 57. (C) Sites III and IV - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 152049 April 64

Figure 58. (C) Sites III and IV - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 152049 April 64

with the M-2, inspection of the imagery shows a total of 106.9* detections, representing 29 percent of the total possible. A total of 35.4 detections were made with the D-2 scanner, which is 11 percent of the total possible detections of 321. This difference in scanner results is attributable to two combined effects - resolution and wavelength sensitivity. As described earlier, the instantaneous field of view of the M-2 scanner used in Project ART was two milliradians, while that of the D-2 was three milliradians. With small, intense thermal sources such as firepots, maximum signal to background ratio is approached as the scanner field of view is reduced until the source just fills the field of view. While the two-milliradian field of view of the M-2 was several times the firepot size at the altitudes flown, the situation nonetheless favored the smaller field of view for maximizing signal to background ratio and, thus, firepot detection. With wavelength, analysis shows that maximum signal to background ratio with firepots against vegetation/terrain is obtained in the 4.5 - 5.5μ band, again favoring the InSb-equipped M-2 scanner. By way of further comparison, at least one firepot detection was realized on each of the passes with the M-2 scanner, whereas eight of the D-2 passes produced no detectable firepot signatures.

Examples of the appearance of this firepot array are given in Figures 59 through 64. Figures 59 and 60 contain a short-wavelength and a long-wavelength imagery sample of the predawn missions. Similar illustrations of the results of daylight missions are given in Figures 61 and 62; Figures 63 and 64 present examples from the post-sunset missions.

After resolution/wavelength, the next most significant parameter in firepot detection was time of day at which the mission was flown. These data are given in Table 3. The table entries are the average number of firepot detections per pass over the array, with the number of passes associated with each entry given parenthetically. These results were somewhat predictable, of course, based on knowledge of diurnal heating and cooling effects. At all wavelengths, the total

*The fractional detection figures result from the averaging of three independent interpretations.

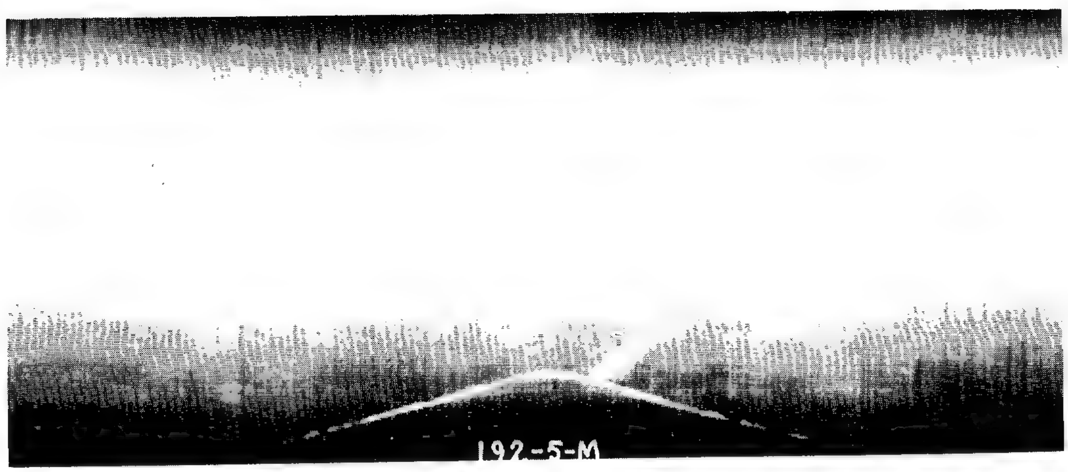

Figure 59. (C) Site V - M-2 Scanner, 1.0-5.5μ,
Altitude 1000 Feet, 150447 April 64

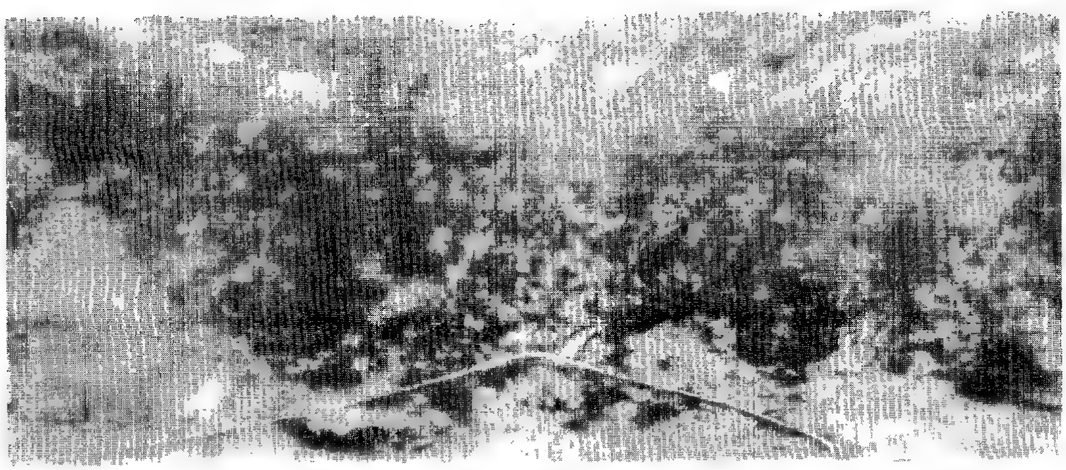

Figure 60. (C) Site V - D-2 Scanner, 8.5-13.5μ,
Altitude 1000 Feet, 150505 April 64

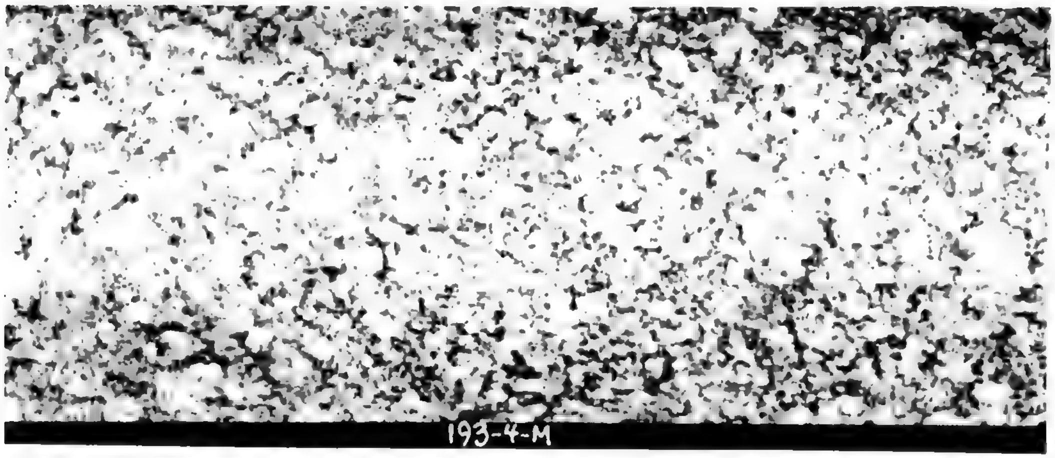

Figure 61. (C) Site V - M-2 Scanner, 1.0-5.5μ,
Altitude 1000 Feet, 150817 April 64

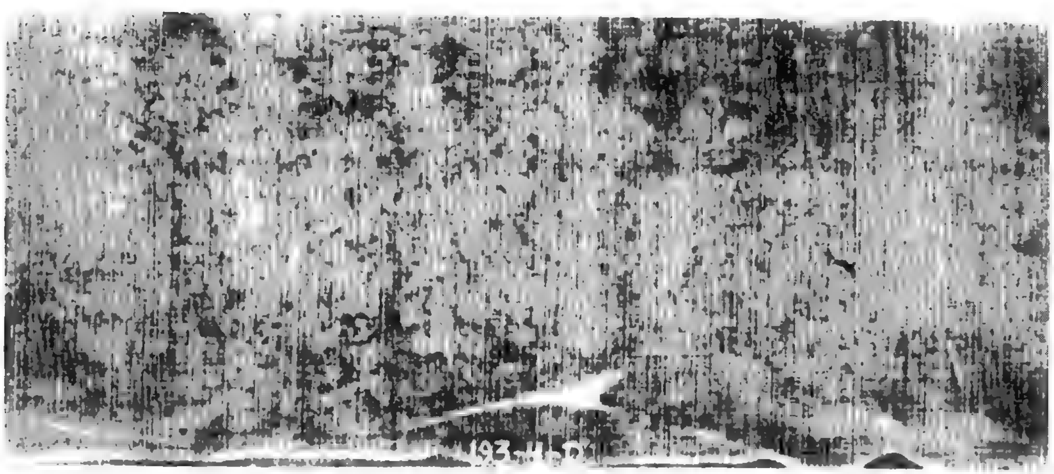

Figure 62. (C) Site V - D-2 Scanner, 8.5-13.5μ,
Altitude 1000 Feet, 150817 April 64

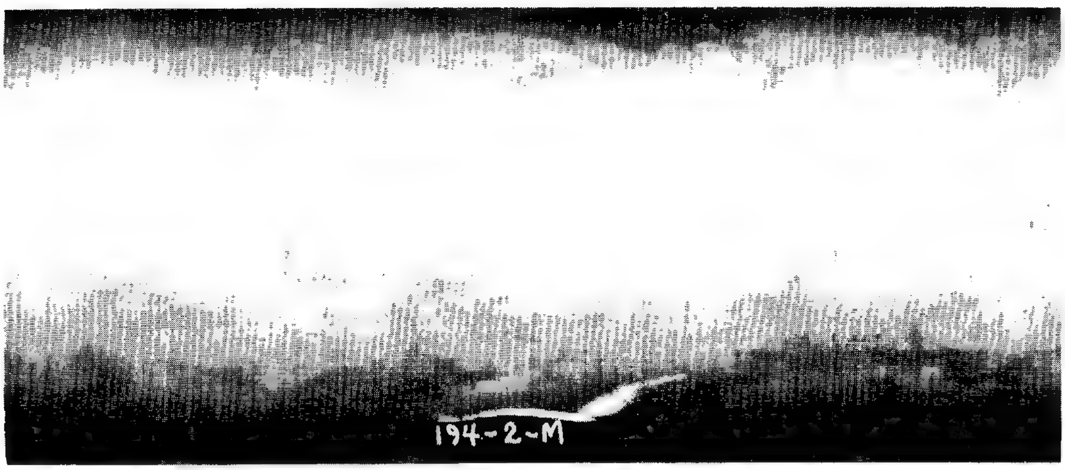

Figure 63. (C) Site V - M-2 Scanner, 1.0-5.5μ,
Altitude 1000 Feet, 152018 April 64

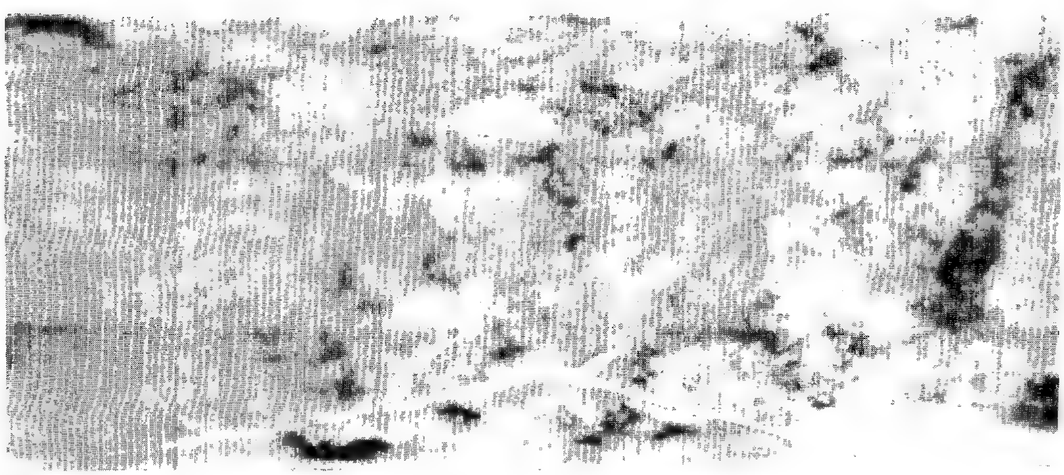

Figure 64. (C) Site V - D-2 Scanner, 8.5-13.5μ,
Altitude 1000 Feet, 152018 April 64

Table 3. Detections per Pass as a Function of Time of Day and Scanner

Time	Scanner	
	M-2	D-2
Predawn	5.0 (9)	2.2 (9)
Post-Sunset	4.4 (8)	1.4 (8)
Daylight	2.7 (10)	0.7 (7)

reflected and emitted thermal energy from terrain and vegetation is maximum during daylight, decreases during the evening, and reaches a minimum during predawn hours. The emitted energy from the firepots remains constant, however, with the result that the firepot/background thermal "contrast" increases from daylight, through evening, to dawn.

Most of the passes over Site V were made at 1000 feet. Only four of the 27 total passes were flown at 500 feet, so that insufficient data is available for comparison of altitude effects in detection of the firepots. There appears to be some detection improvement at the lower altitude, but the small sample prevents any justified conclusions.

F. SITE VIII

1. General Results

Fourteen JC-47J daylight passes, 25 JC-47J night passes, and 11 U-1A daylight passes were flown over this site. The radar malfunctioned during the four SLAR passes over this area, hence any further attempt at radar penetration of the jungle canopy was not possible. The one firepot at this site was detected on all infrared passes at the two altitudes tested (1000 and 1800 feet). At all altitudes only the first three vehicles were detected and identified on the conventional photography. Infrared coverage at the higher altitudes of 1000 and 1800 feet provided consistent detection of the first three vehicles also.

2. Comparative Sensor Cover

Figure 65 is a black and white photograph taken from 800 feet over site VIII, and

Figure 66 is a color photograph of the same site. The color photograph here has suffered the greater resolution degradation, but the original color photography reveals the presence of three vehicles and evidence of a fourth, and its black and white counterpart reveals the distinct presence of only three vehicles. (These three vehicles were either in the clear or only partially concealed.) Once again as was noted previously, the color photography offers only a minimal improvement over the conventional Plus-X.

3. Infrared Evaluation

A total of 17 passes were attempted by the Project MICHIGAN aircraft over this target site. First coverage of 6 passes was attempted between 2020 and 2057 hours, with target coverage by the M-2 scanner obtained on only two of the passes and by the wider-angle D-2 on five of the passes. Missing the target site was attributed to navigational uncertainty and low air-to-ground visibility due to haze. On this evening mission, the M-2 was equipped with an unfiltered InSb detector (1.0 - 5.5μ) and the D-2 scanner with an 8.5 - 13.5μ Ge:Hg detector. A predawn mission was accomplished the following morning between 0407 and 0434 hours. Since the liquid helium supply required for Ge:Hg detector operation had been depleted on the mission of the previous evening, both the M-2 and the D-2 scanners were equipped with unfiltered InSb (1.0 - 5.5μ) detectors for this predawn mission over Site VIII. Of the six passes attempted, only two of the M-2 passes included coverage of the Site VIII area. No acceptable imagery was obtained with the short-wavelength equipped D-2 scanner. Finally, a daylight mission between 0814 and 0851 hours was attempted under marginal flying conditions, which were low overcast and rain. Neither scanner produced any acceptable imagery of Site VIII on this daylight mission.

With the predawn mission, the firepot at Site VIII was detected on both successful passes with the short-wavelength M-2 scanner. While close inspection of the imagery negatives suggests a few of the vehicles apparent as cold objects on the trail, the signatures are not adequate to be labelled "detections." Figure 67 shows these equivocal results.

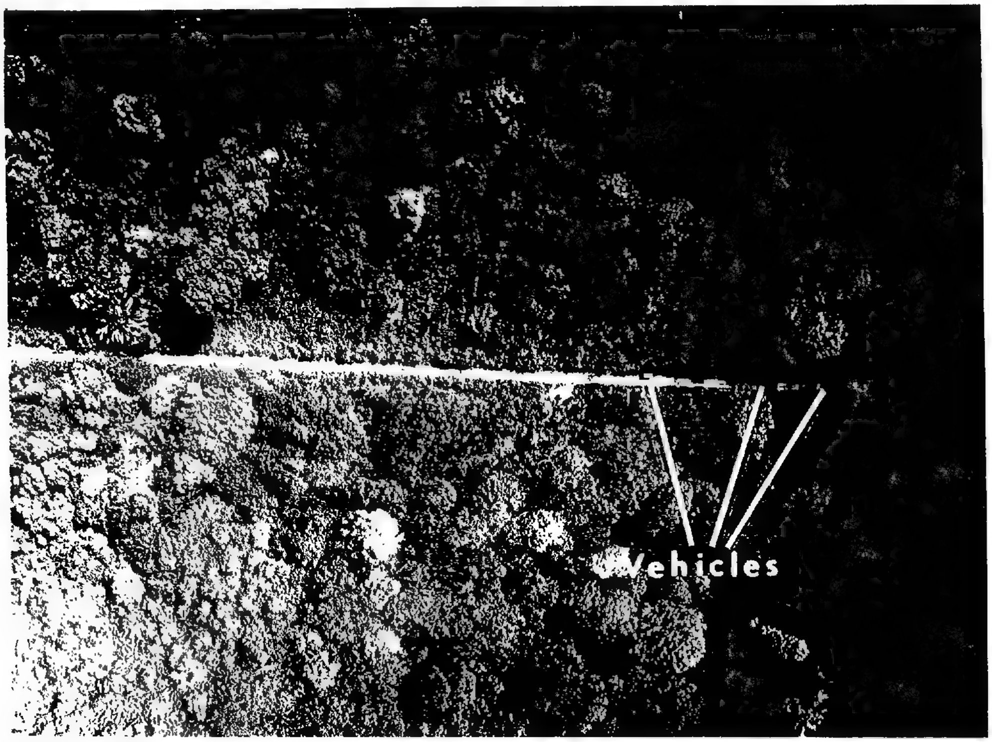

Figure 65. (U) Site VIII - KA-50A, Black and White, WR G12

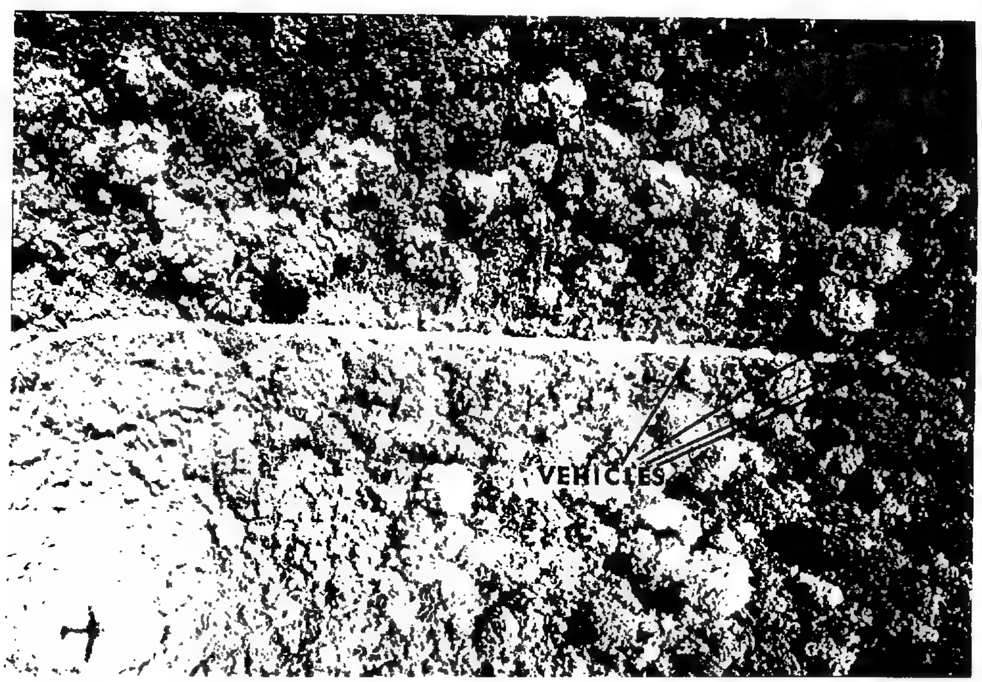

Figure 66. (U) Site VIII - KA-50A, Color (Ektachrome), WR 1A

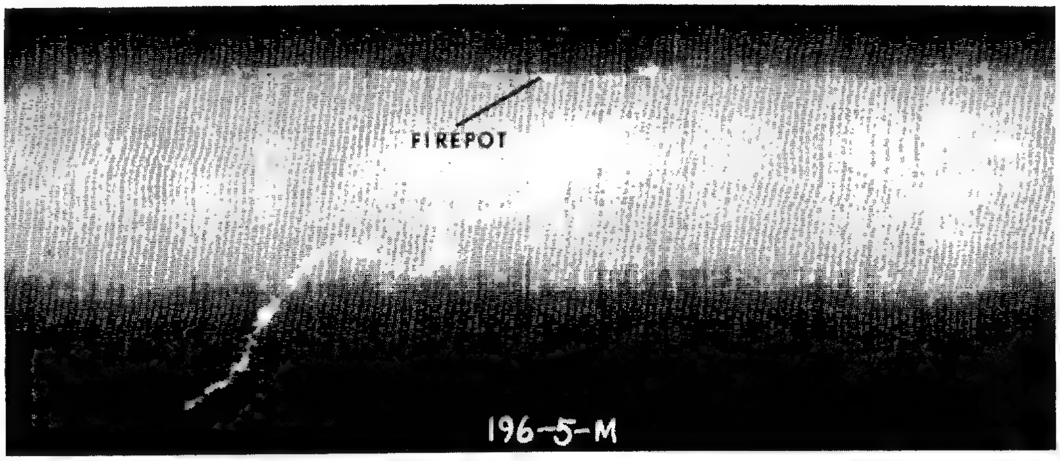

Figure 67. (C) Site VIII - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 170423 April 64

Figures 68 and 69 illustrate the somewhat more successful mission flown in the evening prior to the predawn mission discussed above. With the firepot, both successful passes with the short-wavelength M-2 scanner provided detectable signatures, with four of five possible detections obtained with the longer-wavelength D-2. Again, none of the target vehicles was detected with any certainty, although some suggestion of colder-than-trail signatures appear in the imagery.

While optimistic conclusions from the results of these missions over Site VIII are difficult, negative conclusions must be tempered by the recognition of the adverse weather conditions under which the missions were attempted. While these conditions did not prevent detection of the intense thermal source represented by the firepot, non-operating vehicles did not provide signatures apparent on the only 1.0 - 5.5μ and 8.5 - 13.5μ imagery available for interpretation.

G. SITE IX

1. General Results

Fourteen JC-47J daylight passes, 25 JC-47J night passes, and eleven U-1A daylight passes were flown over this site. The firepot in the clearing was repeatedly imaged by the infrared sensors and thus provided the required point of reference on the infrared record; however, at no time was there any evidence of the road

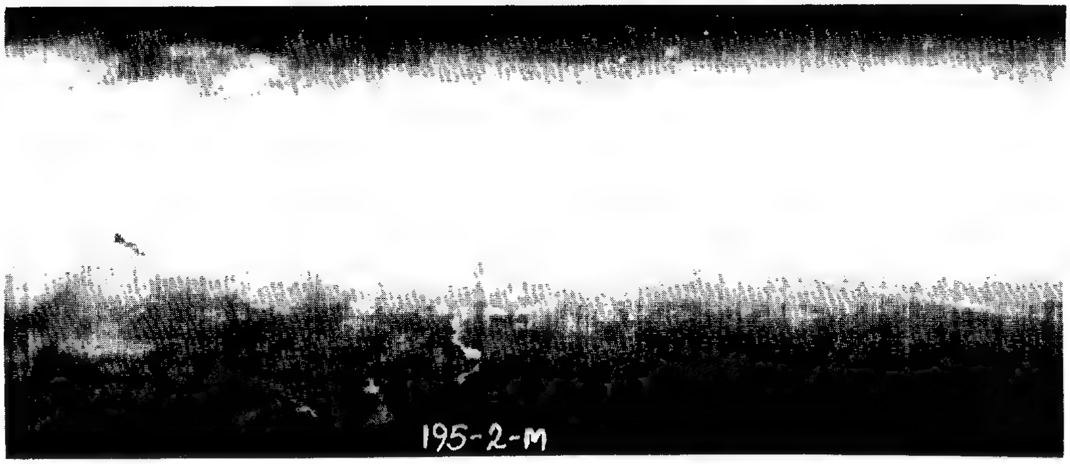

Figure 68. (C) Site VIII - M-2 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 162020 April 64

Figure 69. (C) Site VIII - D-2 Scanner, 8.5-13.5μ, Altitude 1000 Feet, 162020 April 64

ambush on either the infrared records or the conventional black and white and Ektachrome photography. It might be mentioned, however, that the ambush was also not detectable from the ground while standing on the trail 5 to 10 feet away (see Figures 19 through 21).

H. SITE X

1. General Results

The firepots in the caves were detected only infrequently by way of the infrared scanners, four times out of a possible 55, whereas the firepot in the bivouac area was consistently detected. The seacaves used during the staging of this site were extremely difficult for an interpreter unfamiliar with the area to detect and identify as such from the photography; however, the interpreters had no trouble in identifying less hidden or more sharply defined ones in this area. In addition, stereoscopic viewing aided little in enhancing the identification of these small, rather well hidden caves, since the caves themselves could not be looked into because they consisted of small areas on the rocky shore which had been cut back by the erosive effect of the ocean waves and tides and thus each cave had a rock overhang that effectively concealed it from overhead view. Vehicles at this site were generally not seen on the photography because of the medium-to-heavy canopy cover. Only the Carryall, which was the least concealed, was consistently detected and identified on the photography and this at only the two larger of the three scales tested, i. e., 1 : 3400 and 1 : 6800. Sunlight reflection from the vehicles was a factor in detection in some cases. Infrared imaging of these vehicles proved a bit more successful with greatest results obtained at night, which indicates once again some infrared canopy penetration. The bivouacing troops were not detectable by either the infrared sensor or on the photography. Several native huts (bohios) of the small group in this area were detected from the photography. SLAR coverage of this site was not attempted.

2. Comparative Sensor Cover

A comparison of the three different films used over this site in the detectability and identifiability of targets shows little difference. The color infrared film once

again proved slightly better than the color or the black and white in those cases where the natural color or concealed or camouflaged appearances of targets tends to blend into the target's surroundings. This was particularly true for bohios in this area. These huts, when at least semiconcealed by the canopy, went undetected on the black and white photography; however, they were readily detected on the camouflage detection film. The age of these huts was also estimated by means of the infrared radiation of the thatched roofs revealed by the color infrared film. A check on the accuracies of these estimates, however, was not possible. Use of the infrared scanner imagery in conjunction with the conventional photography aids in the surveillance of this area, since the vehicles were to some extent detected better on the scanner.

3. Infrared Evaluation

Twenty passes were attempted by the Project MICHIGAN aircraft over this target site. Eight of these passes, only three of which were successful, were made between 0356 and 0438 hours; seven passes, six of which were successful, were made between 0807 and 0833 hours; and five passes were made from 2014 and 2029 hours, with four being successful. The seven missed passes, i.e., failure to fly over the target site, are attributable to low visibility and lack of adequate landmarks in the site area. Since the liquid-helium supply had been expended, no long-wavelength ($8.5 - 13.5\mu$) imagery of this site was obtained. In the discussion that follows, only imagery acquired by the M-1 scanner with an InSb detector is considered.

The predawn mission was flown at 1000 feet under wet, overcast conditions. The M-1 scanner was equipped with an unfiltered InSb ($1.0 - 5.5\mu$) detector for this mission. On the three successful passes of this mission, the firepot was detected each time. Vehicles were detected on only one pass. The vehicles detected were the two engine-on vehicles and the engine-off 3/4-ton truck due south of the firepot. Figure 70 shows these detections.

During the six successful daylight passes, wavelength samples, both $1.0 - 5.5\mu$ and $4.5 - 5.5\mu$, were obtained at altitudes of 500 and 1000 feet. None of the

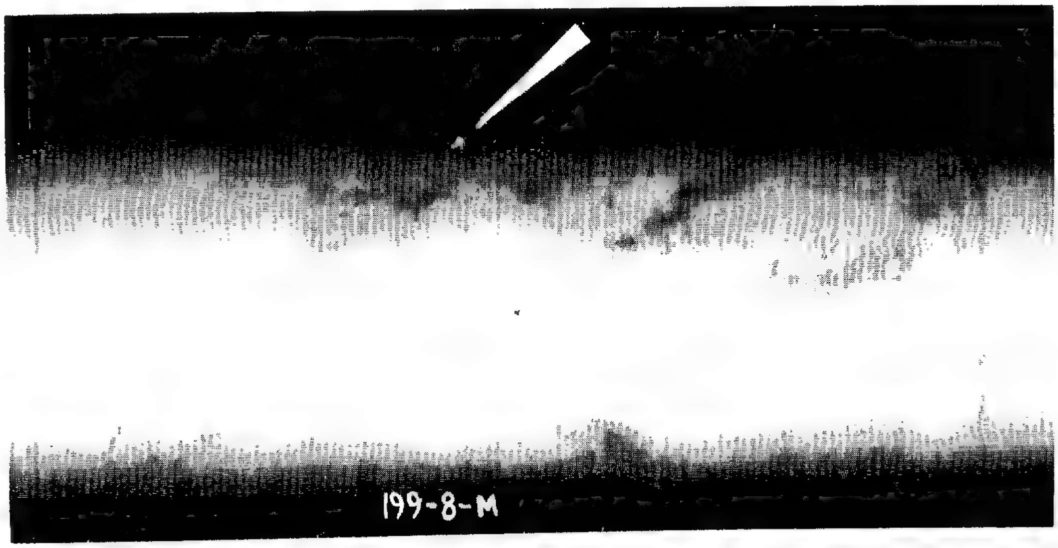

Figure 70. (C) Site X - M-1 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 200420 April 64

target components was detected on the one 1.0 - 5.5μ pass at 1000 feet, and only the firepot was detected at 500 feet. With the 4.5 - 5.5μ band, only the firepot was detected on one of the two passes at 1000 feet, whereas all target components except the 2-1/2 ton truck east of the firepot were detected on the other 1000-foot pass with the 4.5 - 5.5μ band. Two 4.5 - 5.5μ passes were also made at 500 feet. One of these passes produced detection of all components except the easternmost 2-1/2 ton truck; the other provided signatures for only the firepot and the engine-on 1/4-ton truck. Figures 71 through 74 illustrate the wavelength and altitude effects.

The four successful passes of the evening mission were flown under hazy, scattered-clouds conditions. At 1000 feet with the M-1 scanner operating at 1.0 - 5.5μ, three of the passes produced firepot detection, and two of these passes included a detectable signature of the engine-on 2-1/2 ton truck. The imagery in Figure 75 is representative of this mission.

While the predawn and post-sunset detections of Site X are meager, the results from the daylight mission again suggest the relative lack of utility of the 1.0 - 5.5μ band in detecting small thermal sources under tropical vegetation. The superiority

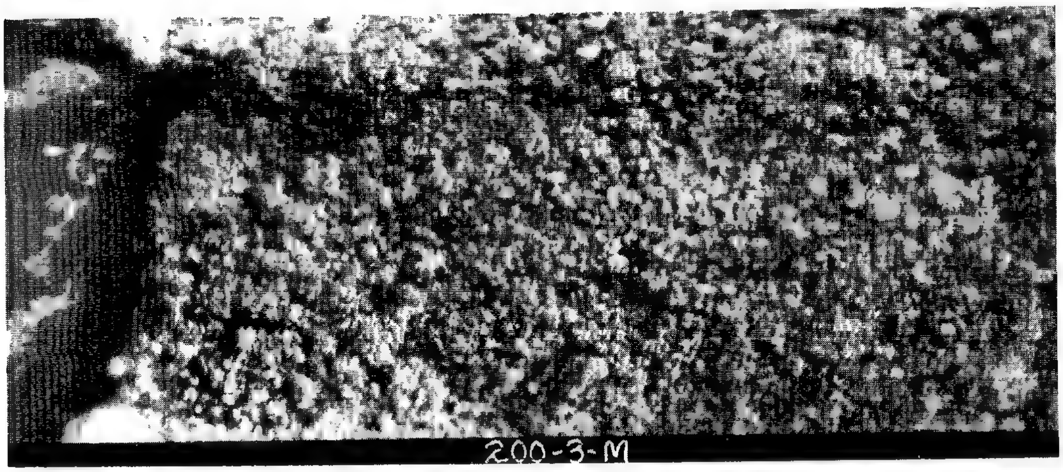

Figure 71. (C) Site X - M-1 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 200810 April 64

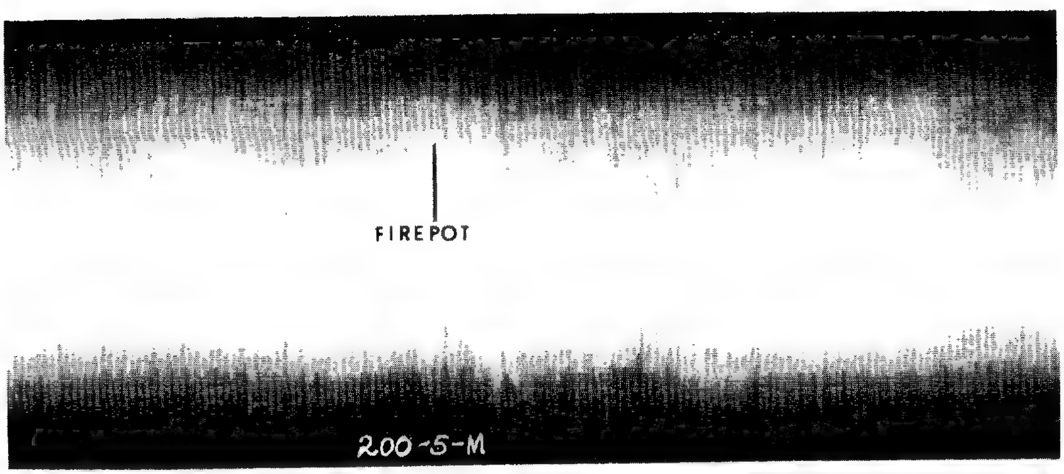

Figure 72. (C) Site X - M-1 Scanner, 4.5-5.5μ, Altitude 1000 Feet, 200821 April 64

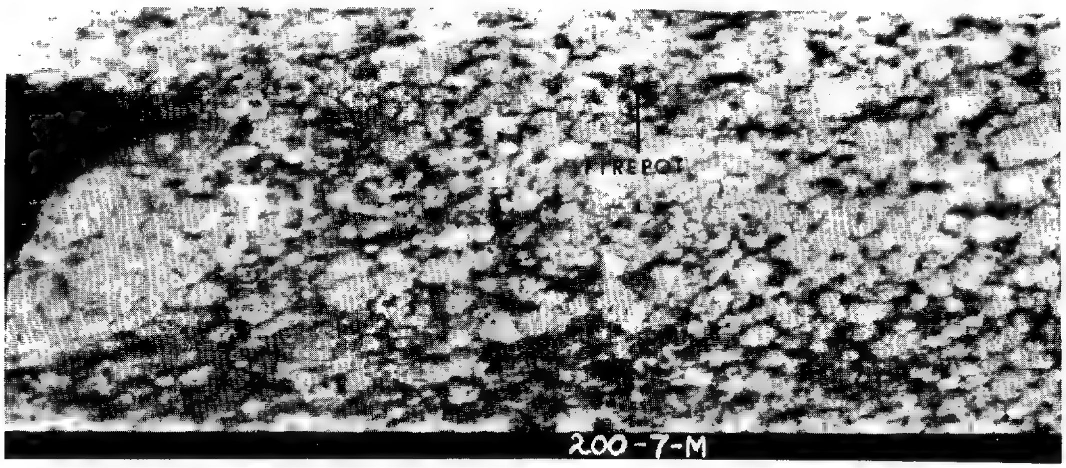

Figure 73. (C) Site X - M-1 Scanner, 1.0-5.5μ, Altitude 500 Feet, 200826 April 64

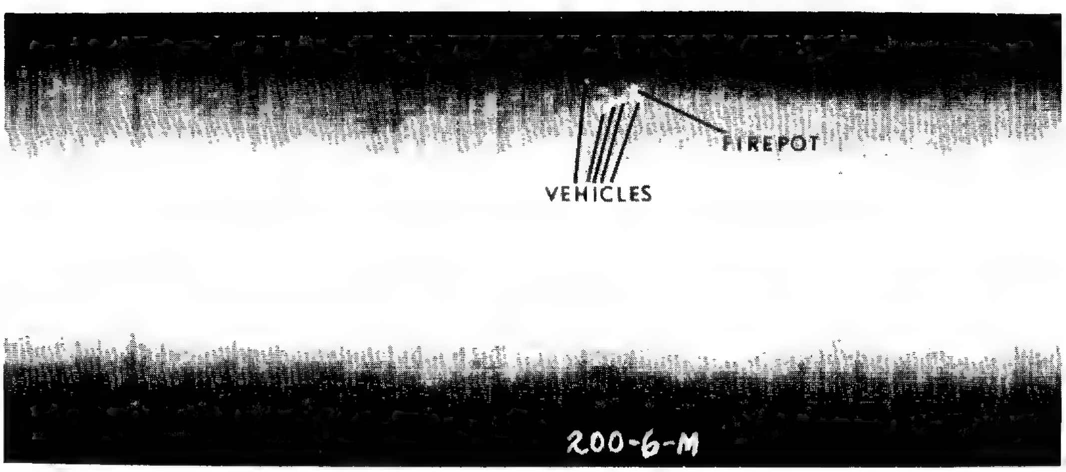

Figure 74. (C) Site X - M-1 Scanner, 4.5-5.5μ, Altitude 500 Feet, 200823 April 64

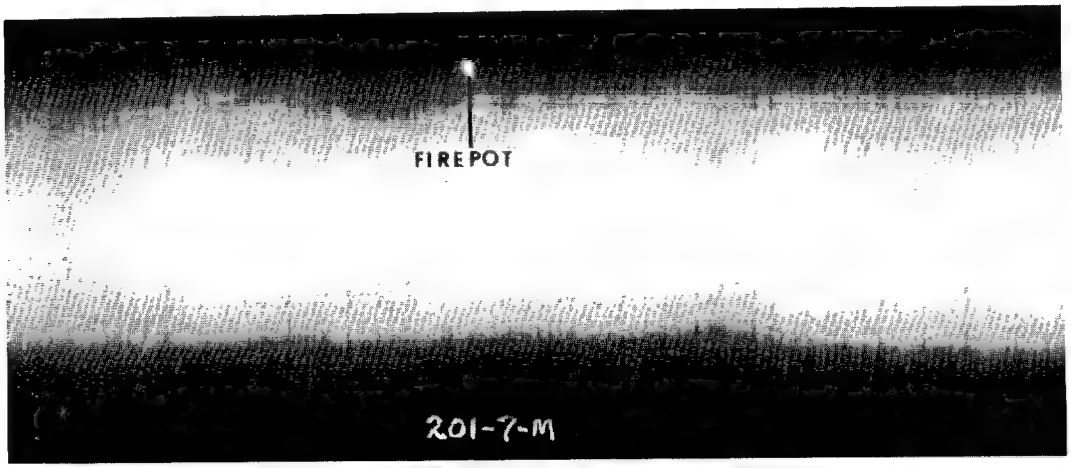

Figure 75. (C) Site X - M-1 Scanner, 1.0-5.5μ, Altitude 1000 Feet, 202029 April 64

of the InSb detector filtered to reject reflected energy from vegetation and terrain is shown in the results from the 4.5 - 5.5μ passes.

I. SUMMARY

Chart 5 is a general synopsis of the degree of success achieved in detecting the vehicles and firepots at each site with the infrared scanners and the cameras and was prepared by lumping all collection conditions together for each of the two types of sensors over each of the eight sites. AN/UAS-5 data is supplied for Site II only. A careful study of this chart suggests the sensor response bar graphs of Figure 76, where no AN/UAS-5 results have been considered. As can be seen from these graphs, there is no significant difference in the detection capabilities of the two types of sensors relative to the hot vehicles in the open at Site I. However, for the light- and medium-canopy-cover conditions, the infrared scanners appear to display a slight, but definite, superiority over the conventional photography relative to these same hot targets. An extrapolation of these graphs beyond the medium-canopy-cover region suggests little detection capability on the part of either sensor for this type of target. Optical detection of the cold vehicles in the open at Site I was about 37 percent better than with the infrared scanners.

Site	Canopy Cover	TARGET - VEHICLES								
		IR						Photo		
		Hot			Cold					
		Possible	Detected	%	Possible	Detected	%	Possible	Detected	%
I	Open	88	84	95	66	48	73	231	231	100
IV	Light	156	136	87	27	6	22	84	60	71
II*	Medium	84	8	10	112	1	1	102	32	31
V	Medium	-	-	-	-	-	-	-	-	-
X	Medium	26	9	35	65	9	14	154	21	14
VIII	Medium to heavy	-	-	-	63	0	0	91	21	23
IX	Medium to heavy	-	-	-	-	-	-	-	-	-
III	Heavy	-	-	-	-	-	-	-	-	-

*Site II: On six returns (IR), could not identify which vehicle. They were assumed to be "engine-on" vehicles.

Site	Canopy Cover	TARGET - FIREPOTS					
		IR			Photo		
		Possible	Detected	%	Possible	Detected	%
I	Open	66	66	100	66	0	0
IV	Light	46	46	100	12	0	0
II	Medium	28	12	43	17	0	0
V	Medium	684	142	21	196	0	0
X	Light	52	44	85	88	0	0
VIII	Light	7	6	86	13	0	0
IX	Medium to heavy	18	12	67	7	0	0
III	Heavy	162	39	24	48	0	0

Chart 5. (C) Percentage of Vehicles and Firepots Detected as a Function of Degree of Canopy Cover

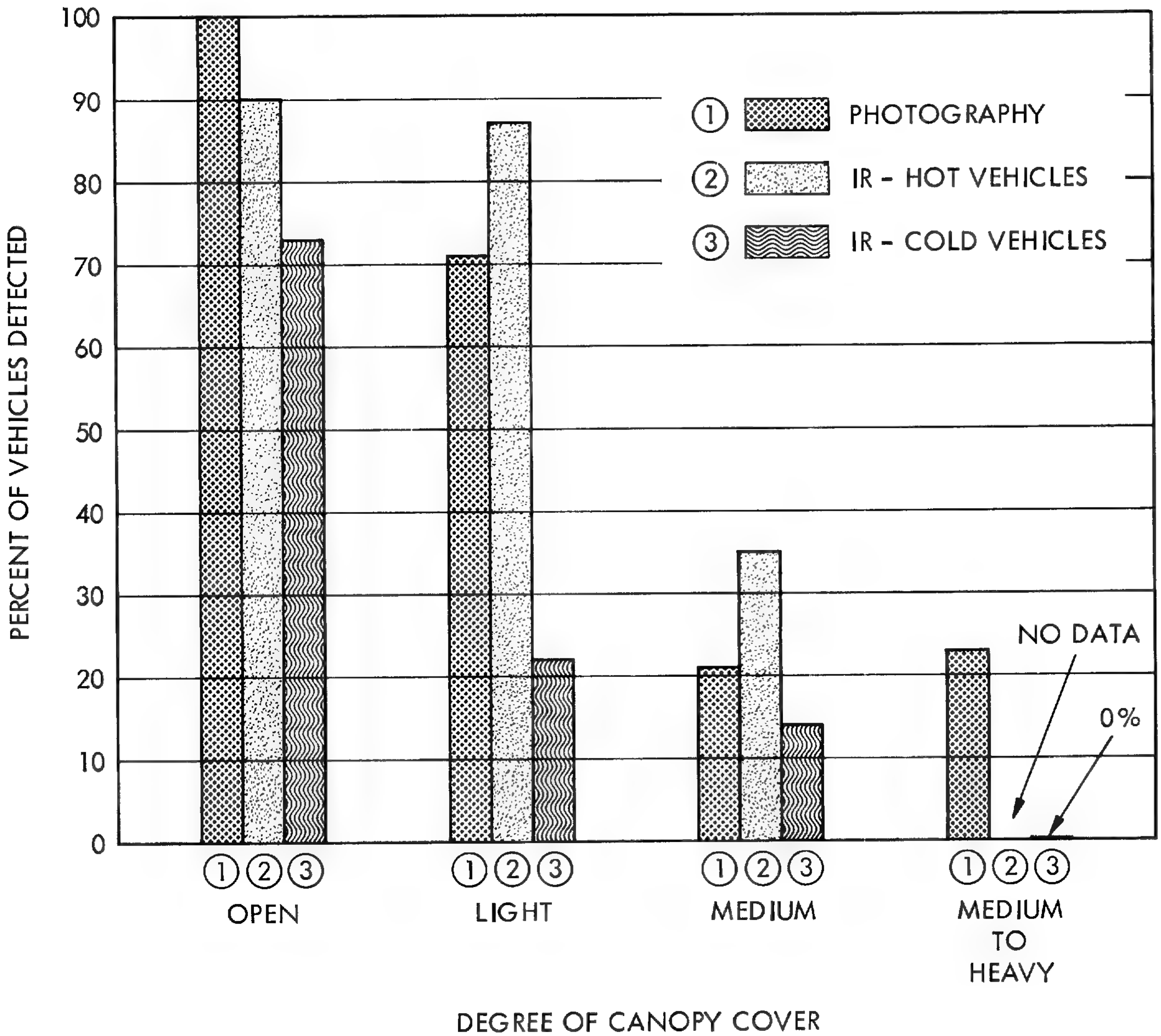

Figure 76. (C) Percentage of Vehicles Detected as a Function of Degree of Canopy Cover

Detection of these targets drops rapidly when moved under canopy, and both systems register very low once even medium-canopy-cover conditions are encountered.

Since the single firepots at Sites VIII and X were used primarily for reference purposes in conjunction with the more heavily concealed vehicles at these sites, they were in these two cases placed in an area of less canopy cover than that typical of the site in general. Hence, on the chart these two firepots are classified as being under only light cover.

SECTION 7

(U) DISCUSSION OF RADIOMETRIC RESULTS

Previous experience with this instrument has shown that the sensing head and electronic unit are influenced by ambient temperature, which causes errors in temperature readout. Warm-up time of the sensing head is nearly one hour. One solution has been to periodically check the calibration by a measurement on melting ice during flight. This check was virtually impossible during this project because of the type of aircraft installation. Therefore, the reliability of the temperature measurements is questionable.

Though the spectral range of the instrument lies in an "atmospheric window," attenuation due to water vapor in the atmosphere is possible, and the high moisture levels in the Fort Sherman area undoubtedly caused some effect on the measurements. Another parameter that affects surface temperature measurement is the emissivity of the surface. Development of a technique using the radiometer to determine emissivities in this spectral range is continuing. Attempts to determine this quantity in the Fort Sherman area were unsatisfactory because of the lack of a cloudless sky, which is needed for such measurements in the field.

It has been found that in temperate climates, the emissivity of vegetation approaches 1.0 and the emissivity of water is 0.98. The rise of water temperature as a normalizing factor is possible in evaluation of this type of data. In the Fort Sherman area, water temperatures were taken routinely by the Panama Canal Co at Cristobal and Gatun. The average water temperature at Cristobal was 26^{o} C and at Gatun 29^{o} C. With this in mind, the following observations are made:

(1) Surface temperatures measured during predawn and after-dusk flights indicated little variation from the surrounding water temperatures.

(2) Temperatures noted during daylight flights (0900 - 1200 hours) over the jungle were usually in the range of 27 to 32°C with occasional rises to 35°C in cleared areas.

(3) Temperatures over man-made objects such as roads, houses, etc were 50°C near noon.

(4) The highest temperatures measured over natural surfaces around noon near 1200 hours were 50°C over dry grassland near the Gatun locks and 45°C over the shoreline northwest of Fort Sherman.

SECTION 8

(C) CONCLUSIONS

The following conclusions regarding the relative merits of the types of imagery obtained during Project ART from the point of view of the detection and identification of counterinsurgency-type targets and vehicular activity as well as observations on equipment operation and maintenance problems are presented based on the limited Project ART exercise.

(1) High temperature, high humidity, extremely dense vegetation, and the nature of counterinsurgency type of targets make the detection and identification of these targets in tropical areas marginal, at best.

(2) The infrared scanners proved their capability to penetrate jungle canopy. However, most targets, including the fires, went undetected under the most extreme cases of canopy cover.

(3) Although personnel were in no case detected with the infrared scanners, their presence can be somewhat inferred from activity indicators (fires, vehicles, etc) to the extent that these are identifiable.

(4) In some cases personnel in the open could be detected and identified on photography at a scale of 1 : 1000.

(5) Detection of small thermal sources in wet tropical environments is maximum with an InSb detector filtered to accept energy in the 4.5 - 5.5μ band in the daytime and with an unfiltered InSb (1.0 - 5.5μ) detector in darkness. This conclusion, however, must be tempered by the knowledge that the experiment was actually run during the dry to wet season transitional period. Thus, weather conditions were not as severe as is the case during at least half of the year.

(6) While by no means completely explored, reconnaissance above 1000 feet with 2 - 3 milliradian scanners is probably not effective.

(7) Color infrared, or camouflage detection, film has considerable value for the detection and identification of objects in open sections of forest trails or in the open grasslands. In general, it appears that this type of film has value in tactical operations beyond its previously assigned limited applications to camouflage detection functions.

(8) The value of black and white films and conventional color film varies widely with the type of target and its background. However, low inherent resolution of color film in addition to the losses incurred in the duplication process argue against its extensive use. Also, processing is difficult. In general, the black and white films have an advantage particularly in view of their relatively high resolution and better duplicability.

(9) A radar such as the AN/APQ-86 used in Project ART can detect objects such as boats on the water and vehicles on trails if the water area or trail is not hidden by the jungle canopy or other obstruction; however, there was no evident microwave penetration of the rain forest itself.

(10) The utility of multisensor imagery in the detection and identification of objects was demonstrated during Project ART. Each sensor type can provide an incremental amount of data in different unique situations. Controlled experiments should continue with a view toward establishing the value and limitation of each sensor over a wide variety of climatic or other environmental conditions so as to establish what combinations of sensors produce the optimum information for given intelligence information requirements.

(11) Operational sensors should be employed in addition to R&D devices in future multisensor tests.

(12) Precise navigation and orientation aids are required in jungle areas for both assuring reconnaissance coverage of a desired area and registering the location of imaged areas to other map references.

(13) The problems associated with the operation and maintenance of the photographic, radar, and infrared equipments and the films while in the tropics seem to significantly increase over those in less humid climates.

(14) The general weather conditions of the tropical rainy season result in high atmospheric humidity and saturated ground surface. High humidity serves to attenuate both the infrared and microwave signals in the path from ground to airborne sensor. Saturation of the ground surface serves to facilitate dissipation of thermal differences at the surface, which has a further degrading effect on the infrared signals available to the infrared scanners.

(15) Low cloud formation, a condition that is prevalent in humid tropical areas such as Panama and Southeast Asia, had detrimental effects on the reconnaissance effort. First, they severely limited the obtaining of imagery at altitudes higher than 1000 feet and thus greatly restricted exploration of this parameter. Second, constant cloud formations block out most of the solar input so that differential heating of surface objects was not possible. This effect is particularly noticeable in the similarity in infrared vegetation and terrain signatures across all three time-of-day samples at the longer wavelengths.

(16) The high humidity conditions experienced also had adverse effects on the infrared scanner systems proper. The non-daylight missions in particular were plagued with detector window frosting, a condition which leads to signal distortion at the scanner input end. In addition, high humidity gives rise to electrical disturbances in infrared detectors with the result that spurious signals are generated and processed by the scanner. As illustrated in Figure 77, these spurious

"moisture-spike" signals can act both to obscure real target signals and create false detections. The most prominent effect of this high-humidity condition on the radar performance was persistent high-voltage arcing.

(17) Automatic film exposure control is extremely important in operating in the tropics because of the rapid changes that take place in cloud cover.

(18) Detection and identification capabilities might possibly have been enhanced if a three-inch lens had been used on the KA-50A cameras. This probably would be the best compromise for tropical reconnaissance from a 500-foot altitude when it is desired to obtain vertical coverage.

(19) Halos surrounding the infrared firepot returns were not observed on any of the firepots used during Project ART. Halos during Project TROPICAN had been reported as being associated with their largest (14-inch) pots. Twelve-inch pots were the largest used during Project ART.

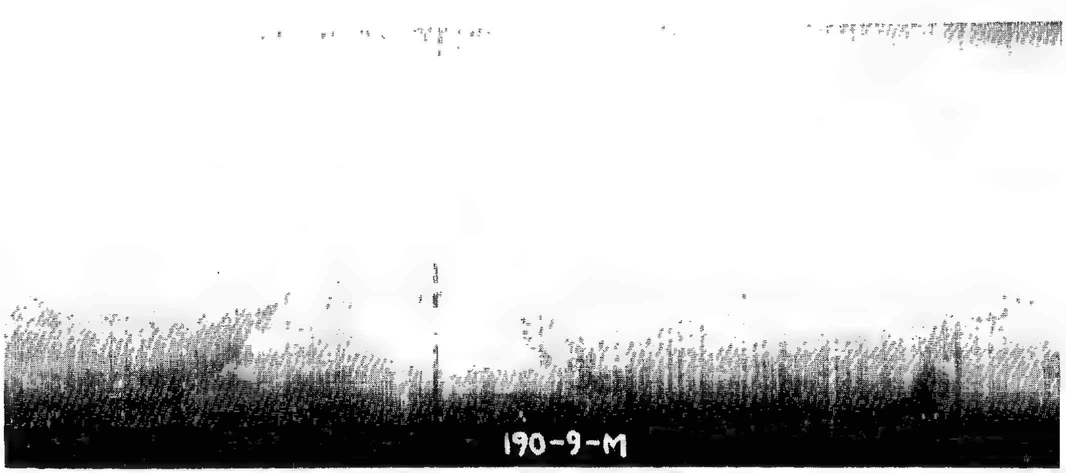

Figure 77. (C) Spurious Signals Associated with Scanner Operation in High Humidity

SECTION 9

(U) ACKNOWLEDGMENTS

The successful acquisition of the high quality imagery, the highly detailed ground truth information, and the required auxiliary data obtained during Project ART were accomplished through the combined efforts of a large group of people representing six different organizations. To list the contribution rendered by each, individually, would be an almost endless task. Particular mention must be made, however, of the efforts rendered by Messrs. Werner Zaayenga (USAEL) and Alfred I. Schwartz (USAPRO) prior to and during the data acquisition phase of Project ART. Mr. Zaayenga was responsible for the over-all planning of the exercise, the transportation and housing of personnel, equipments, and supplies in the Canal Zone, for all logistic problems involved, and for attending to the prodigious amount of details attendant to such an operation. While Mr. Schwartz was primarily occupied with directing the timely and realistic staging of the ground situations during the imagery collection effort, he gave unstintingly of his time and ability during all phases of the project from its inception to his valuable constructive criticism during the preparation of this final report. Of the Project MICHIGAN personnel, Messrs. Dale S. Fisher and Dana C. Parker are cited for effective management of the airborne operation and the ground documentation effort respectively.

The accomplishment of the long and tedious job of analyzing the voluminous amount of imagery and ground truth data during the data reduction and imagery analysis phase was due in large part to the persistent and diligent efforts of three members of the image interpretation group of USAEL, SFC Rex E. Bostick, S/Sgt Jack Shibuya, and Sp4 David E. Ruth. SFC Bostick also rendered inestimable assistance during the preparation of this report.

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Acknowledgment is also made of the assistance provided by Lt Col Thomas J. Agnor (USATTC), who made available the required Tropic Test Center facilities in the Canal Zone and aided greatly in the test coordination, to Mr. Harold A. Pontecorvo (USAEL) for his assistance in imagery processing, film duplication, and technical assistance during data collection and reduction and project reporting, to Mr. Andrew C. Combs (USAEL), who supplied for this report the radiometer description and the discussion of the radiometric results, to Mr. John R. Rieken (HRB-Singer), who through his general knowledge of Viet Cong tactics and the terrain of South Vietnam, assisted greatly in the authentic staging of the counter-insurgency situations and in providing detailed site sketches, and finally to Miss Marilyn Doney of Goodyear Aerospace Corporation, who performed the editing of the draft of this report and who also coordinated the efforts of the Art, Photographic, and Publications Departments of Goodyear Aerospace Corporation during the publication of this report.

SECTION 10

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SECTION 11

(U) LIST OF ABBREVIATIONS

AAFCS	Antiaircraft Fire Control System
AFB	Air Force Base
AMS	Army Map Service
Anti-Vig	Anti-vignetting
Bn	Battalion
C	Centigrade
CD	Camouflage detection
COIN	Counterinsurgency
cps	Cycles per second
CRT	Cathode ray tube
E. I.	Exposure index
Ge:Hg	Mercury-doped germanium
imc	Image motion compensation
Inf	Infantry
InSb	Indium antimonide
IR	Infrared
mc	Megacycles
MG	Machine gun
PRT	Portable radiation thermometer
RADC	Rome Air Development Center
SLAR	Side-looking airborne radar
Sp	Special
T	Ton
USAECOM	US Army Electronic Command
USAEL	US Army Electronic Laboratories
USAPRO	US Army Personnel Research Office
USATTC	US Army Tropic Test Center
VAC	Volts alternating current
VDC	Volts direct current
V/H	Velocity/Height
Wr	Wratten
μ	(When used alone) microns (10^{-6} meter)
μ	(When used with second) microseconds (10^{-6} second)

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